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# THE NEWER INSECTICIDES, REPELLENTS AND RODENTICIDES OF VALUE IN THE FIELD OF PUBLIC HEALTH[1]

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The exigencies of the recent war were largely responsible for the great increase in research on insecticides, repellents and rodenticides that has resulted in the development of an almost bewildering series of compounds previously unknown in the pest control field. This research, which is apparently being continued with unabated vigour and enthusiasm, has been carried out by government agencies, in universities, and by industry in various countries, but particularly in the United States and the United Kingdom, where many thousands of materials have been tested to ascertain their possible value as pesticides.

Among them a number have proved of outstanding value, or show promise of value, in the field of public health and hygiene, and it is the purpose of this paper to present briefly some pertinent facts obtained from various sources relating to their use in this field.

## INSECTICIDES

### *DDT or 1-trichloro-2, 2-bis(p-chlorophenyl)-ethane*

At the present time DDT is the most outstanding and the most widely used of the newer insecticides. Its remarkable performance in combating insect vectors of disease during the latter part of the war and since, has received an unprecedented amount of publicity. The story of the original discovery of the compound in 1874 by an obscure German chemist named Othmar Zeidler (14), and its rediscovery as an insecticide by research workers of the Swiss dyestuffs firm of J. R. Geigy, S.A., about 65 years later (1, 5) is well known, and its unusual qualities as an insecticide, notably its extraordinary effectiveness against many species and its prolonged residual action; its formulation, application, and the precautions that should attend its use have been discussed in many hundreds of technical and popular articles.

DDT first became available to the Canadian public early in 1945, in the form of a "barn" spray, essentially a 5% solution in kerosene for application to the interior walls and ceilings of buildings housing livestock, to control flies. Since then, numerous proprietary products containing DDT have appeared on the market, including oil solutions, emulsions, powders (for application in the dry state and as water suspensions), and aerosols, and are being widely used.

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All these products, and indeed all pesticides offered for sale in Canada, have to be registered under the Pest Control Products Act. Under the regulations of this Act the ingredients, guarantee, purpose, directions, and text of labels are reviewed and are subject to approval by the Science Service of the Dominion Department of Agriculture, before registration is granted. This is intended to ensure that the public may purchase and use such products with confidence in accordance with the claims and directions of the manufacturer or vendor.

At the present time all products containing 0.5% or more of DDT must be labelled as poisons. Standard amounts of DDT that may be included in proprietary insecticides in Canada have been set tentatively by the Pesticides Administration.

Oil sprays for application in buildings consist of two general types known respectively as surface or residual sprays, and air or space sprays. DDT surface sprays consist essentially of 5% by weight of DDT in refined kerosene. They are intended for direct application to surfaces where they leave a deposit of DDT crystals that may continue to kill insects over a prolonged period. Some of them also contain a small percentage of another insecticide to increase the speed of "knockdown" when the spray is applied.

DDT air or space sprays contain sufficient pyrethrum extract or thiocyanates to knock down and kill a certain proportion of insects even without the addition of DDT. Up to $\frac{1}{2}$ of 1% of DDT may be added to increase the percentage of insects killed. These sprays are used as ordinary fly sprays and do not give a prolonged residual effect. Air sprays prepared specifically for use against crawling insects such as cockroaches and bedbugs may contain up to 1% of DDT.

DDT emulsions for use in buildings may consist of 25% DDT in oil solution plus an emulsifying agent. These are prepared for use as a 5% DDT surface or residual spray by mixing 1 part of the emulsion to 4 parts of water. The chief advantage of using the emulsion is the absence of fire hazard during the spraying operation.

DDT powders consist of DDT ground with an inert diluent such as pyrophyllite or talc. Other insecticides may be added to increase the speed of knockdown. The concentration of DDT in powders containing no other insecticide ingredient, and intended for use in the dry form against external parasites of man and animals and household and industrial insect pests is 10%. Concentrations as high as 50% are available for use in water suspensions. In this case 1 lb. of powder mixed with 1 gal. of water would produce a water suspension of approximately 5% DDT suitable for application as a residual spray.

The aerosol "bombs" that have come into popular use during the past year usually contain DDT, an auxiliary solvent, pyrethrum extract, and Freon as the propellant. When the valve at the top of the bomb is opened a fog-like mist is emitted and dispersed through the atmosphere by the Freon gas. Aerosols were used extensively during the war to kill flies and mosquitoes in buildings and other shelters primarily to protect the Armed Forces from insect-borne disease, but they may also be used to destroy other species of insects.

The remarkable insecticidal efficiency and residual toxicity of DDT makes it possible by the proper application of appropriate formulations containing this chemical to deal much more effectively with infestations of insect pests of importance to public health and hygiene than in the past. This is especially true in the case of those all too prevalent species, the house fly and the bedbug. The simple but thorough application of DDT in spray or dust form to places wherein the bedbug hides or with which it must come in contact in order to reach its host, eliminates the pest and prevents reinfestation for many months, and does away with the necessity of expensive, inconvenient, dangerous and only temporarily effective fumigation. The application of DDT residual sprays to the interior of buildings of all kinds wherever flies are troublesome, plus the periodic spraying or proper disposal of fly breeding materials, if carried out on a sufficiently general scale, could largely dispose of the fly nuisance in whole communities. An example of this in a limited area has been mentioned in another article (13), which also contains reference to a reported marked reduction in cases of intestinal upsets in Ontario Farm Service Force summer camps, which apparently resulted from the effective use of DDT in controlling flies.

Cockroaches are another pest that can be completely eradicated from infested buildings by the efficient use of DDT. Formulations containing both DDT and pyrethrum are particularly effective for this purpose.

Mosquitoes are even more susceptible to DDT than house flies, and minute deposits of the chemical left on indoor surfaces by treating them with a residual spray may remain toxic to these insects for many weeks. DDT in oil solution, emulsion, or water suspension applied as a fine spray to vegetation and other resting places of the adults at a rate of 8 oz. or less of DDT per acre will give considerable relief from the attacks of mosquitoes outdoors. About 4 oz. or less of DDT per acre properly dispersed on the breeding places kills the larvae of both culicine and anopheline forms.

Fleas and lice also are readily destroyed by DDT.

*DDD or 1,1-dichloro-2, 2-bis(p-chlorophenyl)-ethane*

This close relative of DDT has also been referred to as TDE, and bears the proprietary name of Rothane. The manufacturers[1] claim that it is one-fifth to one-tenth as toxic as DDT to warm-blooded animals, but Bishopp (2) indicates that this may be in dispute. It is reported to give a knockdown and kill of house flies comparable to DDT, and to be promising in powder formulations against ectoparasites. Bishopp states that it is more toxic than DDT against anopheline larvae, but has a slower knockdown and less persistent action against lice.

*666 or 1,2,3,4,5,6-hexachlorocyclohexane*[2]

The term 666 is derived from the empirical formula $C_6H_6Cl_6$. The compound is also referred to as benzene hexachloride. The best account of this outstanding insecticide has been given by Slade (11). It was first made by Michael Faraday, who described the process in the *Philosophical Transactions* of 1825. Its insecticidal properties were unknown until demonstrated

[1] Rohm & Haas Co., Philadelphia.
[2] See also Haller, H. L. & C. V. Bowen, "Basic facts about benzene hexachloride", Agric. Chem. 11(1) 15-17, Jan., 1947.

in England during the war by research workers of Imperial Chemical Industries. Early in 1943 they determined that its toxicity to insects was due to the gamma-isomer, named "gammexane" by Slade, which was present to the extent of 10 to 12% in the crude product. Like DDT it is practically insoluble in water but readily soluble in a number of organic solvents. It is prepared for use in the form of powders, oil solutions and emulsions.

Crude benzene hexachloride has been used by the British Army to control house fly breeding. McGovran and Piquett (8) showed that on a weight basis gamma-benzene hexachloride is about 10 times as toxic as DDT, and over 100 times as toxic as borax against fly larvae in breeding media.

Against adult house flies gamma-benzene hexachloride is more toxic than DDT, Slade reporting a 73% kill with 0.01% in an odourless base, as compared with 51% with twice that concentration of DDT. As gamma-benzene hexachloride is more volatile than DDT, residual deposits of it on surfaces are less persistent against flies and mosquitoes than comparable deposits of DDT.

The gamma-isomer has also been reported as highly toxic to human lice, bedbugs, fleas on man and domestic animals, cockroaches, crickets, wasps, and ticks (Acarina).

A pronounced disadvantage of crude benzene hexachloride is its persistent and penetrating musty odour. Efforts are being made to reduce this. The pure gamma-isomer is almost odourless. Formulations containing this insecticide are not commercially available in Canada at the present time (November, 1946).

*1068*

Kearns *et al.* (7) described this compound as a chlorinated hydrocarbon with the empirical formula $C_{10}H_6Cl_8$, "isolated readily as a viscous, colourless, odourless liquid . . . . readily soluble in all proportions in most organic solvents". It may be formulated for insecticidal purposes in powder form or as an oil solution or emulsion. Laboratory tests indicated its volatility and residual effect against insects to be intermediate between DDT and gamma-benzene hexachloride. As a larvicide against the common malaria mosquito it was comparable to these two compounds, but exceeded DDT in its toxicity to adult house flies and the American cockroach. Bishopp (3) states that it is outstandingly effective against body lice "but less persistent than DDT or 3956." In 1 or 2% solution in deodorized kerosene it has been found very effective against the common German cockroach.

*3956*

Another new insecticide, a chlorinated bicyclic terpene, is reported to have been developed in a co-operative project by the University of Delaware and the Hercules Company. So far, it appears to have been referred to only as "compound 3956" or "Hercules Toxicant 3956." In contact and residual sprays, according to Bishopp (3) it is apparently less toxic to house flies than DDT, but more toxic and more persistent than the latter against body lice. Indications are that various species of household insects are susceptible to it, and it has also been reported to be an effective mosquito larvicide.

*Benzyl Benzoate*

Mellanby (9) reported that emulsions containing 20% of benzyl benzoate when painted over the entire body from the neck downwards effected over 95% of cures of scabies[1] in one treatment.

During the war the United States Bureau of Entomology (1) developed an emulsion concentrate for lice and scabies consisting of benzyl benzoate, 68 parts (by weight); DDT, 6 parts; benzocaine, 12 parts; and Tween 80, 14 parts, diluted for use 1 : 5 with water. For head lice and crab lice the aqueous emulsion is sprayed or thoroughly rubbed into the infested hair, and kills the eggs as well as the motile stages of the lice. For scabies the same dilution is sprayed or sponged on the entire body except the head, using about 2 to 3 oz. The subject should not bathe for 24 hours after treatment.

*Synergists*

Synergists, or activators, which increase the insecticidal efficiency of pyrethrum have been of great value in ameliorating the effects of the serious pyrethrum shortage that developed during the war years. Isobutyl undecylenamide, oil of sesame and its derivative sesamin, and piperonyl cyclohexanone have been widely used in this connection. A new compound, reported to be a very effective and fast-acting insecticide in combination with even minute amounts of pyrethrum, is piperonyl butoxide.

## REPELLENTS

During the war marked progress was made in the development of efficient repellents to protect man from the attacks of biting flies, especially mosquitoes, but also blackflies, punkies, other bloodsucking insects and mites. A considerable number of preparations were tested under field conditions at localities in Quebec, Ontario and British Columbia, during the spring and summer seasons of 1942, 1943, and 1944, by officers of the Division of Entomology, assisted by members of the staff of the Division of Plant Protection. Some of the repellent formulae were prepared at Ottawa and others were received from the United Kingdom and the United States, most of the latter from E. F. Knipling, of the Orlando, Fla., laboratory, of the United States Bureau of Entomology and Plant Quarantine.

Against common Canadian mosquitoes, chiefly *Aedes* spp., the best of the repellent mixtures in popular use before the war, containing pyrethrum extract, oil of citronella, spirits of camphor, oil of tar, etc., gave an average protection (calculated to the second bite on treated skin) ranging from about 1 to $2\frac{1}{2}$ hours.

Outstanding among the newer repellents were Rutgers 612 (2-ethyl-1, 3-hexanediol), which gave an average protection of nearly 5 hours; dimethyl phthalate, the average protection from which was about 4 hours, and Indalone (*n*-butyl mesityl oxide oxalate), which protected for about 3 hours. A mixture of these three consisting of 3 parts dimethyl phthalate and 1 part each of Rutgers 612 and Indalone, received from the Orlando laboratory gave protection to the second bite for an average period of $5\frac{1}{2}$ hours.

[1] Caused by the itch mite, *Sarcoptes scabiei* DeG.

In 1944 a sample of 2-phenyl cyclohexanol received from the Orlando laboratory gave the longest average period of protection of any of the materials tested, namely, 6½ hours. Recently, Jachowski and Pijoan (6) of the United States Naval Medical Research Institute, at Bethesda, Md., reported excellent results in repelling various species of mosquitoes, certain other bloodsucking insects and mites, with a mixture referred to as N.M.R.I.—448, consisting of 7 parts (by vol.) of 2-phenyl cyclohexanol and 3 parts of 2-cyclohexyl cyclohexanol.

Travis and Morton (12) also recommend dimethyl carbate as an alternative to ethyl hexanediol in the 3 : 1 : 1 formula mentioned in a previous paragraph.

In using any of these repellents one should avoid getting them in the eyes, as they cause a temporary stinging sensation. Furthermore, one should bear in mind that these chemicals are solvents of varnishes, paints and plastics, and should be kept from contact with such surfaces or materials. When applied to clothing the repellents retain their effectiveness for much longer periods than on the skin. Wide-mesh head nets which allow good vision and are comforable to wear, but untreated might permit the entrance of mosquitoes, can be made insect-proof for two or three days by dipping them in dimethyl phthalate or other effective repellent material.

## RODENTICIDES

Two outstanding new rodenticides were developed recently by research workers in the United States, namely, alpha-naphthyl-thiourea ("Antu") and sodium fluoroacetate ("1080"). Proprietary preparations containing Antu began to appear on the Canadian market in 1946 and are coming into increasingly popular use, but 1080, because it is extremely dangerous to man and domestic animals, has not yet been allowed entry into this country.

### *Alpha-naphthyl-thiourea (Antu)*

This compound is highly toxic to the common Norway or brown rat, but much less so to other animals. Its value as a rat killer was discovered by Dr. Curt P. Richter (10), of the Johns Hopkins School of Medicine, in the course of taste tests with various chemical substances.

It is a fine greyish powder, insoluble in water, stable, non-volatile, and non-irritating to the human skin. To the brown rat it is 5 or 6 times more toxic than thallium sulphate, one of the most potent of pre-war rat killers, 3 or 4 mg. of Antu being sufficient to kill a large adult rat. Rats (and also dogs[1]) which have ingested a lethal dose die from acute pulmonary edema and pleural effusion. Death usually occurs in 12 to 48 hours but may take longer. Rats which have taken a sub-lethal dose rapidly build up a tolerance which may persist for a month or more. Young rats are more resistant to the poison than the adults.

Antu may be used as a dust or tracking poison mixed with a diluent such as flour or pyrophyllite. This is dusted down rat holes and along rat runways

[1] Antu is about one-fifth as toxic to dogs as to the brown rat.

and on and around acceptable foods. It is advisable also to use baits as well as the dust form. These may be prepared by thoroughly and evenly mixing 2 or 3% by weight of Antu with attractive food materials. As little as 0.5% has been recommended, but this low dosage increases the chances of rats, especially young rats, obtaining a sub-lethal dose and acquiring temporary immunity. Significantly higher percentages may repel the animals. Another method of application is to make a 1 or 2% water suspension of Antu, or dust it on the surface of water, and expose this in small containers in places where the rats are likely to drink it.

*Sodium Fluoroacetate (1080)*

This compound was developed as a rodenticide by the United States Fish and Wild Life Service in their search for an efficient substitute for thallium sulphate, which was in short supply during the war. It is a fluffy white powder, odourless and almost tasteless and very soluble in water. It is extremely toxic to rats, mice and field rodents but also unfortunately, to other warm-blooded animals. For instance, it is many times more toxic to dogs and cats than to the brown rat. Less than one-fiftieth of an ounce is believed to be a lethal dose for man.

A simple method of using 1080 against rats and mice consists of dissolving ½ oz. in 1 gal. (U.S.) of water (0.4%) and exposing this in small containers in the haunts of the animals. They are reported to prefer this solution to plain water. It is also used in bait form, 1 oz. being thoroughly mixed with 28 lb. of attractive food (0.2%). Great care has to be taken to safeguard humans and domestic animals.

In the United States the sale and use of 1080 is carefully controlled and supervised, and its application is supervised by public health authorities and pest control operators. In Canada its use is not yet permitted. It is hazardous to humans because of its extreme toxicity, its ready solubility in water, and the practical impossibility of detecting its presence by smell or taste. Moreover, there is no known antidote. Its action on the heart is reported to be the primary cause of death.

Frick and Boebel (4) recently published an interesting paper entitled "Clinical observations of 1080 poisoning". A 1100 lb. horse was given 2.5 gm. of 1080 in 100 cc. of water administered by stomach tube. Another 850 lb. horse was given two doses, each of 0.9 gm. in 30 cc. of water, intravenously, one hour apart. The first horse died in 10 hours, and the second in 7 hours after the initial dose. The only post-mortem symptom in both horses was the condition of the blood which was black and thick, like tar. Muscle, liver and heart tissues from these horses were fed to dogs. All of the animals appeared normal except the dog which ate the heart tissue: this was dead in 18 hours, and its blood was black, thick and tarry. The authors concluded that 1080 apparently has an affinity for cardiac tissue and its action is primarily on the heart. The lethal dose for the horse was established as 5 mg. per kg., the same as for the brown rat.

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# RELATIVE POTENCIES FOR POULTRY OF THE CANADIAN STANDARD REFERENCE COD LIVER OIL AND THE BRITISH PROVISIONAL STANDARD PREPARATION OF VITAMIN $D_3$[1]

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At the present time there are in general use two vitamin D standards for assaying the potency of antirachitic substances for poultry feeding. A subsidiary standard reference cod liver oil is used in Canada and the United States and a provisional standard preparation of vitamin $D_3$, which is under the control of the British Standards Institute (B.S.I.), is used in Great Britain.

The Canadian Subsidiary Standard Reference Cod Liver Oil (Canadian standard) is identical with the United States Pharmacopoeial (U.S.P.) No. 2 reference cod liver oil (6). The potency of the Canadian standard was established against the International standard solution of irradiated ergosterol using rats and contains 115 International Units (I.U.) of vitamin D per gram. The potency of the Canadian standard for poultry is expressed also in chick units as defined by the Association of Official Agricultural Chemists (A.O.A.C.) (1). It contains 115 A.O.A.C. chick units of vitamin D per gram.

The B.S.I. provisional standard is a solution of pure crystalline vitamin $D_3$ in pure vitamin D-free olive oil; one milligram of this solution contains 0.025 micrograms of the crystalline vitamin (3). The B.S.I. unit of antirachitic vitamin D activity is defined as the specific activity of one milligram of the provisional standard preparation.

Until recent years, it had been considered that the relationship between the antirachitic activity of vitamin $D_3$ and the vitamin D of pure cod liver oil, the latter assayed with rats against the International standard, was the same in both rats and chicks. In 1942, however, preliminary work by the Government accredited laboratories[5] for vitamin D assay in Canada (10) indicated that this relationship did not exist in the chick and that vitamin $D_3$ had a somewhat greater potency than 40 units per microgram of the pure crystalline product. Similar results have been reported by the Animal Vitamin Research Council (11). These studies were also of a preliminary nature.

Furthermore, the concept had prevailed that vitamin $D_2$ and vitamin $D_3$ had equal antirachitic activity for the rat. Recently, however, Gridgeman (7) made an extensive study of the relative potencies of these forms of vitamin D. Using a special statistical design for Vitamin D assay, involving analysis of variance and covariance, he made simultaneous comparisons, by the rat assay, of the potencies of vitamin $D_3$, vitamin $D_2$ and the International standard. Both the bone ash method and the line test technique

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were used and the following results obtained on the pooled data: vitamin $D_2$ = 36.0 I.U. per $\mu$gm.; (P = 0.95) limits 32.0 to 39.9; vitamin $D_3$ = 46.4 I.U. per $\mu$gm. (P = 0.95) limits 41.7 to 52.2. The ratio vitamin $D_3$ : vitamin $D_2$ was found to be 1.29 : 1.00 (P = 0.95) limits 1.15 to 1.48. Gridgeman (8) also assembled all the pertinent bioassays of vitamins $D_2$ and $D_3$ done in his laboratory, involving over 3600 animals, and analysed the data statistically. This study showed the following potencies for the two forms of vitamin D : vitamin $D_2$ = 35.7 I.U. per $\mu$gm. (P = 0.95, limits of error approx. $\pm 2\%$), vitamin $D_3$ = 46.6 I.U. per $\mu$gm. (P = 0.95, limits of error approx. $\pm 5\%$); the "rat" potency ratio vitamin $D_3$ : vitamin $D_2$ = 1.31 : 1.00 (P = 0.95, limits of error approx. $\pm 6\%$).

In addition, there have been reports from Great Britain (cited by Waddell (11) ) that unsatisfactory agreement was obtained between assays made against the B.S.I. standard and the U.S.P. No. 2 Reference Cod Liver Oil which, as stated above, is identical with the Canadian standard.

In the light of these reports, it was considered of importance to study further the relative potencies of the Canadian standard and the B.S.I. standard for poultry. This investigation was made using three criteria, namely, the ash content of the tibiae as recommended by the A.O.A.C. (1), the B.S.I. radiographic method (3) and the ash content of the toes, the latter being a method which recently has received considerable attention by workers in this field (2) (4) (5). The results of these studies are presented in this communication.

## EXPERIMENTAL METHODS

The A.O.A.C. procedure (1) for assaying vitamin D for poultry was used, with the exception that 60 chicks were employed per level of vitamin D, being divided equally between 2 pens on each level. Five levels of both the Canadian standard and the B.S.I. standard, at 6.64, 10, 15, 22.5 and 33.75 units per 100 grams of diet were used. The potency of the Canadian standard was taken as 115 A.O.A.C. chick units of vitamin D per gram of oil. Since previous work in this laboratory had indicated that the potency of the B.S.I. standard solution of vitamin D was in excess of 1000 A.O.A.C. chick units per gram, the present assays were made on the assumption that the B.S.I. standard had a potency of 1200 A.O.A.C. chick units per gram of solution. The assays were repeated 3 times—a total of 1800 chicks being used for the tests.

All the left tibiae were ashed individually, while the corresponding right tibiae were X-rayed and tarsometatarsal distances were measured[1] as outlined in the B.S.I. method for radiographic procedure (3). In the toe method, the middle toe of the left foot was cut off at the third joint from the end. The toes from each group were pooled and dried in previously weighed weighing bottles at 135° C. for 2 hours without previous extraction with fat solvents. They were then weighed, and ashed at 850° C. for 2 hours.

The potency and fiducial limits were calculated from the bone ash values, and the radiographic data on the tibiae, by the B.S.I. method (3). In the case of the data on toes, in which the per cent ash was determined on the pooled samples, the statistical method of Knudsen and Tolle (9) was employed for the calculation of potency.

[1] We are indebted to Dr. A. R. G. Emslie, Vitamin Assay Laboratory, Experimental Farm, Ottawa, Canada, for the radiographic determinations.

TABLE 1.—ANTIRACHITIC EFFICACY OF THE BRITISH STANDARD INSTITUTE PROVISIONAL STANDARD PREPARATION OF VITAMIN D EXPRESSED IN A.O.A.C. CHICK UNITS PER GRAM OF SOLUTION

| Date | Assumed Potency* | Assayed Potency | | | | |
|---|---|---|---|---|---|---|
| | | Tibiae Ash | | Radiographic (log. t.m.t.) | | Toe Ash*** |
| | | Potency | Limits** | Potency | Limits** | |
| Feb. 9 | 1200 | 1220 | 1090 – 1370 (89 – 112%) | 1400 | 1240 – 1580 (89 – 112%) | 1450 |
| Feb. 23 | 1200 | 1430 | 1310 – 1580 (91 – 110%) | 1280 | 1130 – 1450 (88 – 113%) | 1470 |
| April 11 | 1200 | 1380 | 1260 – 1510 (91 – 109%) | 1190 | 1030 – 1380 (86 – 115%) | 1100 |
| Mean | | 1342 | 1209 – 1476 (90 – 110%) | 1288 | 1133 – 1468 (88 – 114%) | 1340 |

* One gram of the standard solution is stated to contain 0.025 mgm. of crystalline vitamin $D_3$ and has a stated potency of 1000 B.S.I. Units of antirachitic vitamin D activity.

** Approximate fiducial limits calculated for 5% point.

*** Toes from each level of vitamin D were pooled for ashing and the potency was calculated by method of Knudsen and Tolle (9).

## RESULTS AND DISCUSSION

The relative potency of the B.S.I. standard was calculated on the basis that the Canadian standard contained 115 units of vitamin D per gram. These values, together with the fiducial limits of the estimates for the B.S.I. standard are given in Table I. The fiducial limits are expressed both in units of vitamin D per gram of solution and in per cent.

The weighted mean of the potency of the vitamin $D_3$ standard was found to be 1342 units per gram, limits 1209 to 1476 ($P = 0.95$) as determined by the ash content of the tibiae, 1288 units per gram, limits 1133 to 1468 ($P = 0.95$) by the radiographic method and 1340 units per gram by the ash content of the toes. The potency calculated by averaging the values given by the three criteria is approximately 1320 units per gram. It may be concluded that the antirachitic activity of the B.S.I. unit of the vitamin $D_3$ standard is approximately 30 per cent greater than the A.O.A.C. unit of the Canadian standard. In other words, the ratio of the two units is approximately 1.3 : 1. It will be noted from the data in Table I that the fiducial limits of the values given by the ash content and the X-ray methods are in no case greater than $\pm 15\%$ of the estimated potency.

It is generally accepted that the antirachitic efficacy of vitamin $D_3$ is equivalent to 40 I.U. per microgram of the crystalline product. In view of the fact that the potency of the Canadian standard originally was established against the International standard for vitamin D and since one I.U. is equivalent to one A.O.A.C. chick unit, it is suggested from our data, indirectly, that one B.S.I. unit is equivalent to 1.3 I.U. Therefore, the efficacy of the vitamin $D_3$ in the B.S.I. standard is equivalent to 52 I.U. per microgram of the crystalline product. These findings are in close agreement with the evidence obtained by Gridgeman (8). This worker assayed a preparation of vitamin $D_3$ against the B.S.I. standard, using

chicks, and the same preparation of vitamin $D_3$ against the International standard using rats. The average rat : chick ratio of the potency of vitamin $D_3$ calculated from his results gives a value of 1.3 : 1. The vitamin $D_3$ was assayed with chicks in Gridgeman's work assuming the potency of the vitamin $D_3$ in the B.S.I. to be 40 I.U. per microgram. Since the same preparation of vitamin $D_3$ was used in both the rat and chick assays the efficacy of the vitamin $D_3$ in the B.S.I. standard for the chick can be calculated from the rat : chick ratio of the potencies of the preparation of vitamin $D_3$, and gives a value of approximately 52 I.U. per microgram of the crystalline product. This efficacy of vitamin $D_3$ in the chick is somewhat greater than the value of 46.6 I.U. per microgram of vitamin $D_3$ for the rat as estimated by Gridgeman (8).

In Britain, a standard test oil was used originally for assay purposes (3). When it became evident that vitamin $D_3$ was the form of vitamin D most efficacious for the chick, and when crystalline $D_3$ became commercially available, the B.S.I. abandoned the standard test oil in favour of a solution of vitamin $D_3$ as a basis of comparison. Furthermore, the United States authorities have been currently investigating the suitability of vitamin $D_3$ as a standard for assaying vitamin D preparations for poultry feeding (11).

In view of these developments, together with the recent trend toward increased use of vitamin $D_3$ in Canadian poultry feeds, the advisability of adopting pure vitamin $D_3$ as a standard in this country deserves serious consideration. In the contemplation of such a change of standard, the results reported above and the findings of other workers assume a special significance.

## SUMMARY

The Provisional Standard Preparation of vitamin $D_3$ of the British Standards Institute has been assayed against the Canadian Standard Reference Cod Liver Oil using three criteria of measurement of antirachitic activity. The potency of the vitamin $D_3$ standard, expressed in A.O.A.C. chick units per gram of solution, was found to be 1342, limits 90–110% ($P = 0.95$), by the ash content of the tibiae, 1288, limits 88–114% ($P = 0.95$), by the radiographic method on tibiae, and 1340 by the ash content of the pooled toes. These values are contrasted with the stated potency of 1000 B.S.I. units per gram of solution of the vitamin $D_3$ standard.

It is evident from these data that the antirachitic activities of the A.O.A.C. unit and the B.S.I. unit are not equivalent but are in a ratio of approximately 1.0 to 1.3.

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# A THRESHER FOR INDIVIDUAL PLANTS[1]

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The need for efficient threshing of individual plants has been the incentive for the origination of many ingenious types of small threshing machines by plants breeders. In 1925, Harrington[3] built a single plant thresher which was used continuously until 1945 in the Cereal Breeding Laboratory at the University of Saskatchewan. In 1946 this machine was remodelled to make it more compact and to increase its cleaning and mechanical efficiency. The cylinder, concave and fan parts from the original machine were used but they were reduced in width.

Figure 1 reveals the construction of the new machine. The drawings are to scale and the parts are as follows: The cylinder and concave are made from laminated blocks of hardwood. The cylinder A is 5 inches wide and 5 inches in diameter. The cylinder teeth are arranged in four rows parallel to the shaft and spaced $\frac{3}{4}$ inch apart in the row. They are made from $\frac{1}{4}$ inch square iron rod $1\frac{1}{2}$ inches long driven into holes drilled $\frac{3}{4}$ inch deep into the cylinder. The concave block B has four rows of teeth placed parallel to the cylinder axis. The first row is placed 1 inch below the top face of the concave block and the other three rows are spaced $1\frac{1}{4}$ inches from each other. The concave teeth are arranged to allow the cylinder teeth to run between them and are fitted in the same manner.

The shaker pan C is made of sheet metal 13 inches long, 5 inches wide and $\frac{3}{4}$ inch deep. The shaker runs in two grooves cut in the walls of the cylinder housing and this is accomplished by forming a lip on each side of the pan to fit freely in these grooves. A reciprocating motion is given to it by an eccentric D with a $\frac{3}{8}$ inch throw.

The fan E is $12\frac{1}{2}$ inches in diameter and has four blades 5 inches wide and $2\frac{1}{2}$ inches deep. The housing has a 3 inch by 6 inch air intake opening on each side immediately above the fan bearings. The air intake opening is adjusted by hinged slides fastened at one end by a screw. The air blast is directed so that the grain drops directly through it into the grain box F.

The grain box F is 7 inches wide, $6\frac{1}{2}$ inches long and 4 inches deep and is made of heavy sheet metal. It is held in place automatically by a hardwood stop G.

The feeder is lined with tin, one piece fitting over the concave block and the other placed so as to throw the heads towards the concave teeth. This tin is notched as shown in Figure 1 to allow the cylinder teeth to pass by. The feeder assembly is hinged to allow inspection of the cylinder. A tin baffle is fastened below the concave block to feed the threshed material on to the shaker pan and to stop grains from bouncing over the back of the pan.

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[2] Cereal Breeding Assistant.
[3] Harrington, J. B. Self-cleaning thresher for single plants. Sci. Agr. 8 : 567-569. 1928.

The cylinder and fan shafts are $\frac{1}{2}$ inch in diameter and the shaker shaft is $\frac{5}{16}$ inch in diameter. The three step pulleys used on the cylinder and fan shafts and the single step pulley on the shaker are all made of hardwood.

The cylinder is driven from the front while the shaker and fan are driven by one belt from the pulley on the back of the cylinder. Power is supplied by a one-quarter horsepower motor. This is placed on a hinged base to adjust the tightness of the belt.

The new thresher has a fan speed which is one-half of the cylinder speed and handles wheat, oats, barley, rye and flax satisfactorily. Wind adjustments are made by opening or closing the air intake.

This machine can thresh as fast as single plants can be inserted and the grain pan emptied as there is practically a continuous fall from cylinder to grain box. Single heads have been threshed at the rate of 350 an hour by one person. Head row plots have also been threshed with this machine. This is done by dividing the sheaf into small enough bunches to insert into the feed opening. The operator holds the straw about eight inches from the heads and inserts a bunch until the heads are threshed. The straw is then withdrawn and discarded.

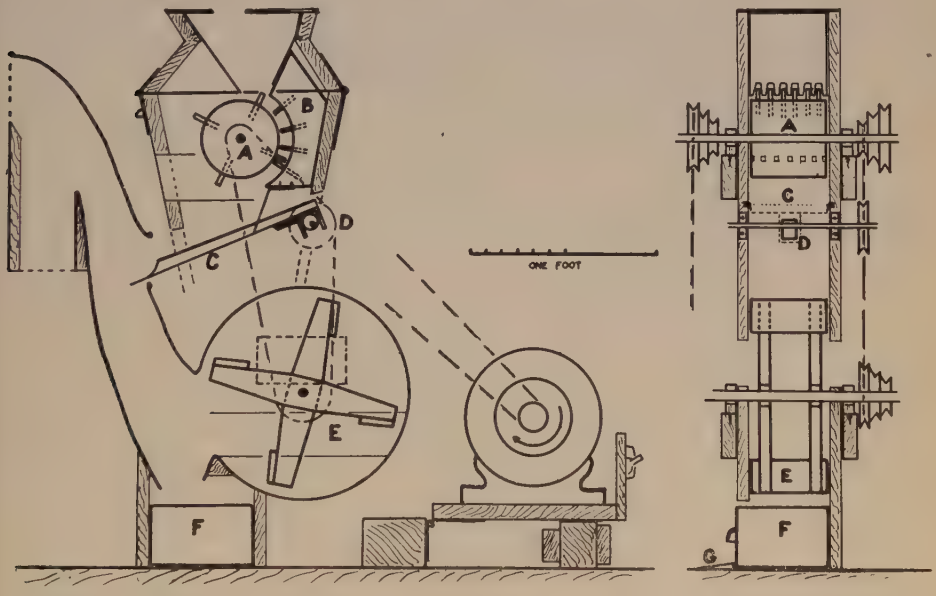


FIGURE 1. Side and End Elevation drawn to scale with detail of measurements omitted (see text).

# A SECOND REPORT ON THE BIENNIAL BEARING OF A BALDWIN ORCHARD[1]

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[Received for publication January 3, 1947]

In a cultural experiment being conducted with apples at the Ontario Horticultural Experiment Station, Baldwin was one of the varieties used. The trees were planted in 1921 and the orchard received uniform treatment until the spring of 1928 when the experiment, "A study of the extent to which apple orchard cultivation may economically be reduced", was begun. The Baldwins began to bear in 1929, and as reported earlier (3), showed a decided biennial bearing habit from the start. This is shown in Table 1 of that report.

## PROCEDURE

This orchard, consisting of Baldwin, McIntosh and Spy, is growing on Vineland sandy loam soil, which is quite level, and apparently very uniform as judged by tree growth. Part receives a minimum of cultivation while the remainder receives regular cultivation. Minimum cultivation means a spring working, sufficient to prepare a good seed bed, and then seeding to

TABLE 1.—TOTAL YIELDS IN POUNDS FOR BALDWIN PER ROW PER YEAR (3 TREES PER ROW) 1939 TO 1944

| Plot | Row | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | Total |
|---|---|---|---|---|---|---|---|---|
| A | 9 | 193 | 1250 | 55 | 1590 | 400 | 2000 | 5488 |
| | 11 | 668 | 735 | 325 | 730 | 1010 | 1040 | 4508 |
| | 13 | 401 | 1090 | 360 | 1440 | 520 | 1760 | 5571 |
| | 15 | 421 | 1315 | 135 | 1260 | 210 | 1850 | 5191 |
| Average | | 421 | 1098 | 219 | 1255 | 535 | 1662 | 5189 |
| B | 17 | 627 | 1365 | 535 | 1190 | 565 | 1195 | 5477 |
| | 19 | 833 | 1455 | 775 | 1180 | 715 | 1260 | 6218 |
| Average | | 730 | 1410 | 655 | 1185 | 640 | 1228 | 5848 |
| C | 21 | 903 | 1300 | 865 | 760 | 1400 | 880 | 6108 |
| | 23 | 733 | 1380 | 360 | 1080 | 690 | 1850 | 6093 |
| Average | | 818 | 1340 | 613 | 920 | 1045 | 1365 | 6101 |
| D | 25 | 878 | 930 | 1010 | 360 | 1520 | 592 | 5290 |
| | 27 | 723 | 1195 | 830 | 1170 | 1175 | 1275 | 6368 |
| | 29 | 1185 | 141 | 1670 | 30 | 1660 | 8 | 4694 |
| | 31 | 1115 | 725 | 1110 | 335 | 1470 | 895 | 5650 |
| | 33 | 970 | 545 | 870 | 220 | 1365 | 479 | 4449 |
| | 35 | 516 | 1210 | 305 | 880 | 890 | 1340 | 5141 |
| Average | | 898 | 791 | 966 | 499 | 1347 | 765 | 5265 |

A. Minimum cultivation to May 15, manure 30 tons per acre 1937 and 20 tons per acre 1938.
B. Minimum cultivation to May 15, manure 20 tons per acre 1935, 1936, 1937, 1938.
C. Regular cultivation to July 15, manure as for B.
D. Regular cultivation to July 15, manure as for A.

[1] Contribution from the Horticultural Experiment Station, Ontario Department of Agriculture, Vineland Station, Ontario, Canada.

[2] Associate in Research.

a green-manure crop, usually about May 15. Regular cultivation consists of thorough cultivation until July 15 and then seeding to the crop used in the minimum-cultivation plots. When a short season crop such as buckwheat is used, the minimum-cultivation plots are rough disked with the last working of the regular-cultivation plots and the whole orchard is then seeded.

The fertility of the soil was low and some trees, particularly McIntosh, showed signs of mineral deficiency which repeated applications of mineral fertilizers failed to alleviate. In order to obtain some information on the response to farm manure under such conditions it was applied at the rate of 20 tons per acre to rows, 17, 19, 21, and 23 across the experiment, to include both cultural treatments. This was done in the fall of 1935. During 1936 no growth response to either trees or green-manure crop was observed and the treatment was repeated that fall. During 1937 there was an appreciable difference in growth of the green-manure crop where manure had been added and in the fall the foliage of the trees in these plots was a richer green. Manure at the same rate was again applied in the fall of 1937 to these plots and the remainder of the orchard received manure at the rate of 30 tons per acre. In the fall of 1938 the whole orchard received manure at the rate of 20 tons per acre. Tabulating them, the manure applications were as follows:

| | Rows 17, 19, 21, 23 | Balance of orchard |
|---|---|---|
| 1935 | 20 | 0 |
| 1936 | 20 | 0 |
| 1937 | 20 | 30 |
| 1938 | 20 | 20 |
| Totals | 80 | 50 |

## RESULTS

No real evidence of the influence of farm manure on annual bearing was noted (3) up to 1938 unless for Rows 17 and 19, which bore again in 1938 following a below-average crop in 1937. This, however, could be chance as happened to Row 29 in the years 1933 and 1934.

The Baldwin trees were removed after the 1944 crop and Table 1 shows the yield record for these trees for 1939 to 1944, inclusive. It will be noted from this table that biennial bearing still persists but that the off year is not as pronounced as in the earlier years (3). Furthermore it will be noted that there is now a difference in on and off years between some plots.

Using the Wilcox formula for biennial bearing index (5),

$$\frac{100 \text{ (difference between two yields)},}{\text{Sum of two yields}}$$

a complete record of the tendency to biennial bearing under the various treatments is shown graphically in Figure 1. In recent years there has

been a general tendency towards annual bearing (the zero line) suggesting that biennial bearing might be overcome to some extent by following a more scientific fertilizer programme.

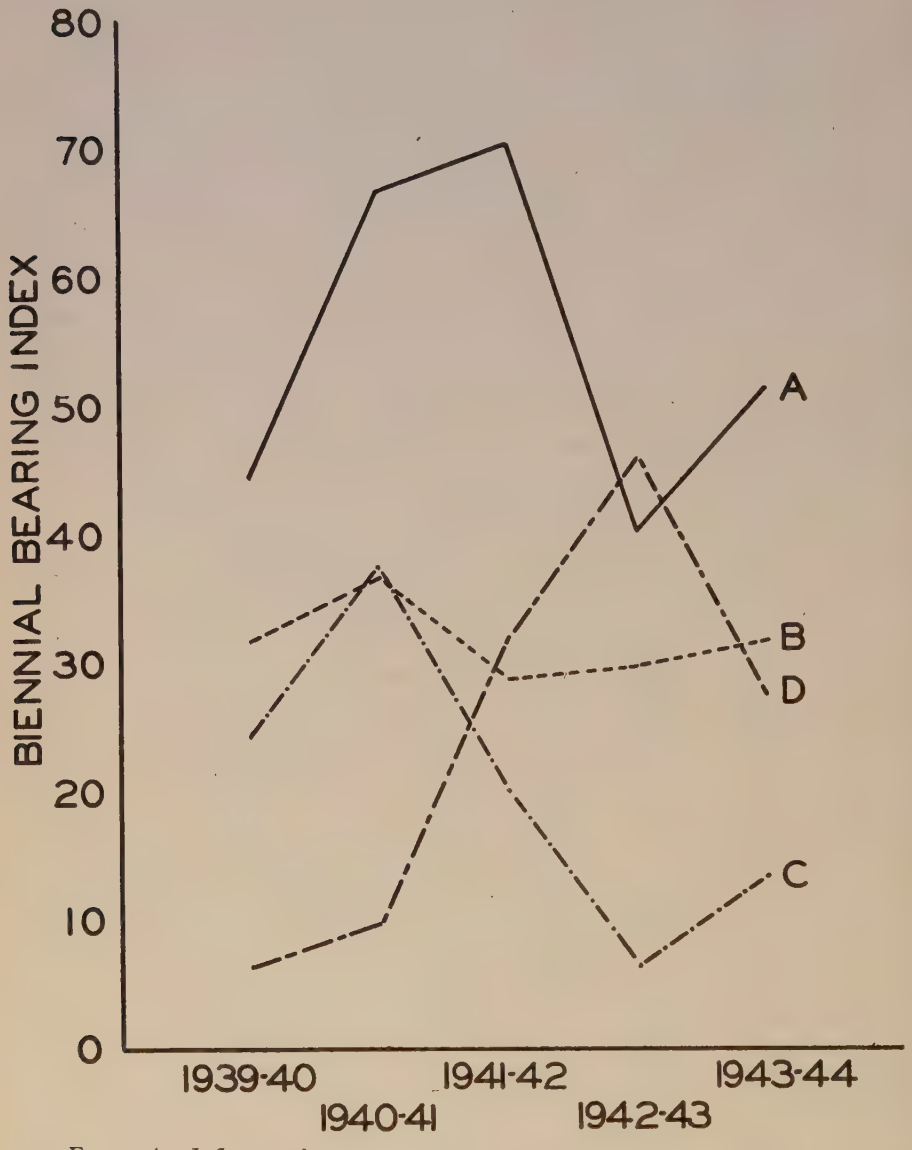


FIGURE 1. Influence of manure on annual bearing of Baldwin as indicated by the Wilcox formula for biennial bearing index. Complete biennial bearing = 100. Complete annual bearing = 0.

A. Minimum cultivation to May 15, manure 30 tons per acre 1937 and 20 tons per acre 1938.
B. Minimum cultivation to May 15, manure 20 tons per acre 1935, 1936, 1937, 1938.
C. Regular cultivation to July 15, manure as for B.
D. Regular cultivation to July 15, manure as for A.

## DISCUSSION

Boynton *et al.* (2) have found indications in two New York McIntosh orchards that the yield is likely to be below optimum when leaf nitrogen in July goes below 1.85% of dry weight. It is probable that a similar minimum could be established for Baldwin and that a proper system of manuring based on such determinations could iron out many of the irregularities of bearing.

This is substantiated to some degree in the yield records and tendency towards annual bearing between Plots A and D which received similar amounts of manure but different cultural treatments. Dickson (4) has shown that minimum cultivation resulted in a reduction in the amount of nitrates in the soil, especially in mid-season. Therefore Plot D although receiving the same amount of manure as Plot A would, because of the extra cultivation and absence of green-manure crop until July 15, have a higher nitrate level and thus receive more immediate benefits from the manure. Plot A should have had extra manure or nitrogen to compensate for the lower nitrate levels in which case a greater tendency towards annual bearing might have been the result.

Beach (1) suggests the same thing but by a different method. He states "The amount of pruning on Baldwin can well be increased soon after trees begin to bear, and this will tend to reduce the strong tendency towards biennial bearing, especially if done in the winter and early spring ahead of the expected heavy blooming."

## CONCLUSIONS

Baldwin trees planted in 1921 have shown a decided biennial bearing habit from the beginning. Biennial bearing has been maintained up to 1944 but the addition of farm manure for several years has to some extent modified this tendency. This suggests that biennial bearing may be at least partially corrected by the application of sufficient quantities of farm manure.

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# ORCHARD FERTILIZER TESTS IN THE OKANAGAN VALLEY[1]

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[Received for publication January 11, 1947]

During the past twenty years, a number of fertilizer tests on apple trees have been conducted by the authors in the Okanagan Valley in British Columbia. Some of these tests have been conducted by the British Columbia Department of Agriculture, some by the Dominion Experimental Station staff at Summerland. Some have been run for short periods only, others for longer periods. In this report, it will be considered sufficient to summarize only the data from those tests that have been continued for periods of 10 years or longer.

The purpose of publishing this report at this time is two-fold. In the first place, some of the tests have been discontinued, and the data on these are now complete. In the second place, the results obtained differ in certain respects from many of those reported in eastern Canada and in the eastern United States.

The climate of the Okanagan Valley is classed as "semi-arid". The precipitation within the area covered by the tests reported herein averages only around 9 to 11 inches annually in the Kaleden-Penticton-Summerland area, and 11 to 13 inches in the East Kelowna-Rutland area. Because of this, irrigation is necessary for growing tree fruits. And because of the low precipitation, there has been comparatively little leaching of phosphorus and potassium from the virgin soils. These and certain of the other soil nutrients are therefore present in higher amounts than in more humid regions. The soils are classed as brown or dark brown earths (1), and are quite variable in texture and depth. They are described more specifically in connection with each plot series.

Those fertilizer tests with apple trees that have been run for more than 10 years have been located in 5 separate orchards, as follows: (1) the King orchard, in Kaleden; (2) the Barnard orchard, in Penticton; (3) the Experimental Station orchard, in Summerland; (4) The Butler orchard, in East Kelowna; and (5) the Willits orchard in Rutland. The first three of these tests were conducted by the Dominion Department of Agriculture, the last two by the British Columbia Department of Agriculture. Following a brief description of the procedures used, the results for each of these plot series will be presented in turn.

## PROCEDURE

In each plot series, the fertilizer was applied annually in a wide band around each tree, within the outer spread of the limbs. Applications were made either in the late fall or early spring. The other orchard operations

[1] Contribution No. 656 from the Division of Horticulture, Dominion Experimental Farms Service, Ottawa, Canada. This paper is also a contribution from the Division of Horticulture, British Columbia Department of Agriculture.

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[3] Provincial District Agriculturist, Kelowna, B.C.

[4] Superintendent, Dominion Experimental Station, Summerland, B.C.

were conducted by the grower concerned, in accordance with his usual procedure. All orchards were irrigated, and were cultivated at least once a year. The type of cover crop grown varied, and will be noted below under each plot series.

Soil samples were collected in 1940 from 3 of the 5 plot series. They were taken with an auger, at depths of 0 to 8 inches, 8 to 24 inches, and 24 to 60 inches, respectively. Where the soil was shallow, sampling was discontinued at the underlying mixture of coarse sand and gravel. The procedures used in soil sampling and in determining the lime content, pH, and moisture holding capacity have already been published (7, 8). The moisture holding capacity was expressed in terms of the number of inches of water held per foot of soil. Organic matter was determined by a modification of the hydrogen peroxide method as outlined by Robinson (3). Soil extracts were obtained by bubbling carbon dioxide through a mixture of 1 part of soil to 2 parts of water for 1 hour, letting it stand over night under an atmosphere of carbon dioxide, and filtering. These extracts were analysed for phosphorus and potassium, and the results were expressed in terms of p.p.m. of P or K in the dry soil. The figures obtained were used to indicate the amounts of available phosphorus and potassium in the soil. When gravel over 3 mm. in size was present, it was screened out at the time of sampling, and all constituents measured were corrected for it, on the assumption that their content in the gravel was zero.

The yield was recorded annually on each tree, in terms of loose, level-full bushel boxes. During certain selected years, the fruit from representative trees in the Barnard and Experimental Station plots was graded by hand for size and colour, that in each grade being weighed. During a 6-year period—1937 to 1942—additional records were taken on 5 selected McIntosh trees in each plot of the Barnard, Butler, and Willits series. These records included increase in trunk circumference and terminal length, the methods of determining which have already been described (4, 5, 6). On these same trees, the "profitable" fruit was recorded from 1939 to 1942. It consisted of those fruits between $2\frac{1}{4}$ and $3\frac{1}{8}$ inches in diameter and with 20% or more of solid red colour (6). Like the total yield, it was recorded in terms of loose bushel boxes. The percentages of profitable fruit were calculated for the years 1939-42 only.

As a measure of the degree of biennial bearing, the average biennial bearing index was determined for each tree. The method of calculating this has been described in a previous paper (6). When a tree bears the same crop year after year, its biennial bearing index is zero; when it bears a heavy crop one year and none the next, in regular succession, its index is 100. Most trees, of course, fall somewhere between these extremes. To obtain the plot average, the index for the whole period is first calculated for each tree, then these individual indices are averaged.

In each series of plots, only one plot was allocated to each fertilizer treatment. The field layouts, therefore, did not lend themselves to statistical analysis. Because of the differences between orchards in their soil, climate, variety, and other factors, it was not feasible to combine the results from all of the series and treat them as one large experiment.

## KING ORCHARD

The soil is a deep, sandy loam, of the Osoyoos Loamy Sand series (2). It has not been analysed for available nutrients. Newtown trees were planted in 1910, 35 feet apart on the square and a tree in the middle of each square. In 1928, 4 plots were laid out side by side, each plot containing 3 rows of 5 trees each. There were no buffer rows between plots. Fertilizers were applied annually from 1928 to 1941, when the experiment was discontinued. The cover crop consisted of vetch and weeds. In order of position, the plots were as follows:

Plot 1 (O): check, no fertilizer.

Plot 2 (N): 10 pounds of nitrate of soda per tree from 1928 to 1941.

Plot 3 (N): 10 pounds of nitrate of lime per tree from 1928 to 1933, and 7.5 pounds of sulphate of ammonia from 1934 to 1941.

Plot 4 (NPK): 10 pounds of nitrate of soda, 2 pounds of triple superphosphate, and 3 pounds of muriate of potash per tree, from 1928 to 1941.

The yields are summarized in Table 1. Since most of the trees tended to bear a heavy crop one year and a light crop the following year, a comparison of the average yields has been made easier by tabulating them by 2-year periods. It will be seen that the differences among the plots were not great enough to be of any significance. No records were taken of tree vigour, but visual observation indicated no lack of vigour in any of the plots.

By 1928, when this test was started, most of the trees had already developed the biennial bearing habit. It will be seen from Table 1 that the highest degree of biennial bearing occurred in Plot 4 (NPK), and the least in Plots 2 (N) and 3 (N). It is questionable whether these differences were caused by the fertilizer treatments.

## BARNARD ORCHARD

The soil in this orchard is a deep silt loam of the Penticton Silt series (2). It contains almost no gravel in the plot area. The trees consisted of McIntosh and Winesap, planted in 1916. They were spaced 40 feet apart

Table 1.—King yield data

| | Plot 1 | Plot 2 | Plot 3 | Plot 4 |
|---|---|---|---|---|
| Treatment | O* | N | N | NPK |
| Yield 1928-29** | 17.1 | 17.7 | 15.8 | 16.2 |
| Yield 1930-31 | 15.2 | 15.3 | 16.3 | 15.5 |
| Yield 1932-33 | 16.0 | 15.7 | 15.9 | 16.5 |
| Yield 1934-35 | 19.6 | 19.1 | 21.0 | 20.9 |
| Yield 1936-37 | 14.3 | 12.1 | 11.1 | 13.5 |
| Yield 1938-39 | 18.4 | 18.3 | 17.4 | 20.4 |
| Yield 1940-41 | 24.9 | 20.4 | 21.2 | 26.6 |
| Average yield per tree | 17.9 | 16.9 | 17.0 | 18.5 |
| Average yield per acre | 1272 | 1201 | 1208 | 1315 |
| Biennial bearing index | 74.7 | 60.8 | 59.9 | 80.5 |

* Treatments: O–no fertilizer; N–nitrogen; P–phosphate; K–potash.
** The yields are expressed in terms of loose bushel boxes.

TABLE 2.—BARNARD YIELD AND VIGOUR DATA

| | Plot 1 | Plot 2 | Plot 3 | Plot 4 |
|---|---|---|---|---|
| Treatment | O* | N | NP | NPK |
| Yield 1932-33** | 16.2 | 21.5 | 19.5 | 19.4 |
| Yield 1934-35 | 10.6 | 22.6 | 17.7 | 18.7 |
| Yield 1936-37 | 13.9 | 19.4 | 19.8 | 20.1 |
| Yield 1938-39 | 17.3 | 22.1 | 18.4 | 19.4 |
| Yield 1940-41 | 10.6 | 17.8 | 14.0 | 15.3 |
| Yield 1942 | 10.7 | 16.4 | 15.3 | 16.0 |
| Average yield per tree | 13.4 | 20.3 | 17.6 | 18.3 |
| Average yield per acre | 747 | 1128 | 975 | 1013 |
| Per cent profitable yield | 94.0 | 93.4 | 94.2 | 94.2 |
| Biennial bearing index | 53.4 | 34.0 | 36.9 | 39.8 |
| Average increase in trunk circumference (cm.) | 2.7 | 2.1 | 2.5 | 2.4 |
| Average terminal length (cm.) | 28.9 | 28.1 | 29.1 | 28.0 |

* Treatments: O—no fertilizer; N—nitrogen; P—phosphate; K—potash.
** The yields are expressed in terms of loose bushel boxes.

on the square, with a tree in the centre of each square. Legume cover crops were turned under frequently. In 1930, 4 plots were laid out side by side; and from then until 1942, when the experiment was discontinued, the following treatments were applied:

PLOT 1 (O): check, no fertilizer.

PLOT 2 (N): 4 pounds of nitrate of soda per tree from 1930 to 1933. Owing to excessive tree vigour, this was discontinued in 1934. From then on, the only nitrogen supplied to this plot and to Plots 3 and 4 was contributed by leguminous cover crops.

PLOT 3 (NP): 15 pounds of 4-10-0 per tree from 1930 to 1933, followed by 3 pounds of triple superphosphate from 1934 to 1942.

PLOT 4 (NPK): 15 pounds of 4-10-0 plus 3 pounds of sulphate of potash per tree from 1930 to 1933, followed by 3 pounds each of triple superphosphate and sulphate of potash from 1934 to 1942.

Plots 2, 3 and 4 each consisted of 3 rows of 5 trees, and contained 9 McIntosh and 6 Winesap trees. Plot 1 consisted of 2 rows of 5 trees, and contained 6 McIntosh and 4 Winesap trees. There were buffer rows between plots.

The yields are summarized by 2-year periods in Table 2. The 1930 and 1932 records were not obtained. The outstanding feature of the table is the lower average yield in the check plot. This occurred primarily because of less nitrogen and less vigour during the early years of the experiment, and consequent smaller size of tree. By 1937, when the growth records were started, the trees in the four plots showed only minor variations in their degree of vigour. It appeared that the use of leguminous cover crops as a common source of nitrogen had induced a comparable degree of vigour in all 4 plots. Another feature to be noted is the greater degree of biennial bearing in the check plot than in the other 3 plots.

In 1935 and 1936, the fruit from 3 McIntosh trees in each plot was graded for size and colour. The results are summarized in Table 3. The size of fruit appeared to depend more on the number of fruits borne than

TABLE 3.—BARNARD SIZE AND COLOUR DATA

| | Plot 1 | Plot 2 | Plot 3 | Plot 4 |
|---|---|---|---|---|
| Treatment | O* | N | NP | NPK |
| 1935 data | | | | |
| Yield per tree, lb. | 159 | 523 | 438 | 309 |
| % fruit under 2½ in. | 5.6 | 2.2 | 5.5 | 7.9 |
| % fruit 2½ to 2¾ in. | 27.9 | 19.0 | 17.7 | 19.0 |
| % fruit 2¾ to 3 in. | 54.9 | 51.1 | 58.2 | 52.5 |
| % fruit over 3 in. | 11.6 | 27.7 | 18.6 | 20.6 |
| % fruit under 25% red | 24.3 | 27.2 | 32.7 | 56.3 |
| % fruit 25 to 50% red | 18.5 | 26.5 | 28.2 | 25.2 |
| % fruit 50 to 75% red | 12.9 | 16.9 | 16.1 | 10.1 |
| % fruit over 75% red | 44.3 | 29.4 | 23.0 | 8.4 |
| 1936 data | | | | |
| Yield per tree, lb. | 525 | 479 | 811 | 675 |
| % fruit under 2½ in. | 3.4 | 3.5 | 6.5 | 4.2 |
| % fruit 2½ to 2¾ in. | 26.2 | 36.6 | 47.4 | 30.4 |
| % fruit 2¾ to 3 in. | 49.0 | 46.1 | 36.8 | 46.6 |
| % fruit over 3 in. | 21.4 | 13.8 | 9.3 | 18.8 |
| % fruit under 25% red | 13.5 | 8.0 | 12.2 | 20.2 |
| % fruit 25 to 50% red | 11.9 | 9.9 | 18.3 | 20.7 |
| % fruit 50 to 75% red | 20.0 | 12.2 | 17.1 | 19.0 |
| % fruit over 75% red | 55.6 | 69.9 | 52.4 | 40.1 |
| 1935-36 averages | | | | |
| % fruit over 2¾ in. | 68.4 | 69.3 | 61.4 | 69.2 |
| % fruit over 50% red colour | 66.4 | 64.2 | 54.3 | 38.8 |

* Treatments: O—no fertilizer; N—nitrogen; P—phosphate; K—potash.

on any other one factor. In other words, the fewer the fruits, the larger the individual apples but the smaller the total crop. For some reason, applications of phosphate and potash were accompanied by decreases in the amount of red colour.

The more pertinent of the soils data are presented in Table 4. As will be seen from the figures for moisture holding capacity, the soil is comparatively uniform in texture throughout the plot area. Like most Okanagan Valley soils, it is somewhat low in organic matter. Free carbonates are present in the subsoil, and close to the surface in Plot 1 as well; and the pH has been affected accordingly. The application of phosphates has increased markedly the available P content in the surface soil, but has had very little if any effect below a depth of 8 inches. For some reason, the available P is much lower in Plot 1 than in Plot 2. Applications of potash have increased the available K content somewhat in the surface soil, but not below a depth of 8 inches.

## EXPERIMENTAL STATION ORCHARD

The soil in this orchard can be classed as a sandy loam, of the Skaha Sandy Loam series (2). It varies considerably in its depth above the underlying mixture of coarse sand and gravel. The trees in the plot area

TABLE 4.—BARNARD SOILS DATA, 1940

| | Depth in in. | Plot 1 | Plot 2 | Plot 3 | Plot 4 |
|---|---|---|---|---|---|
| Treatment | — | O* | N | NP | NPK |
| Organic matter, % | 0– 8 | 1.5 | 2.9 | 2.7 | 2.6 |
| | 8–24 | 0.6 | 1.3 | 1.0 | 1.1 |
| | 24–60 | 0.3 | 0.9 | 0.6 | 0.5 |
| Lime, % | 0– 8 | 1.4 | 0.0 | 0.0 | 0.0 |
| | 8–24 | 5.2 | 2.1 | 0.1 | 0.6 |
| | 24–60 | 2.8 | 5.2 | 3.9 | 5.4 |
| pH | 0– 8 | 7.61 | 6.85 | 6.28 | 6.36 |
| | 8–24 | 8.19 | 7.88 | 7.47 | 7.75 |
| | 24–60 | 8.29 | 8.08 | 8.13 | 8.13 |
| Moisture capacity** | 0– 8 | 3.6 | 3.6 | 3.6 | 3.5 |
| | 8–24 | 3.4 | 3.5 | 3.3 | 3.3 |
| | 24–60 | 3.1 | 3.4 | 3.0 | 3.4 |
| P content, p.p.m. | 0– 8 | 0.8 | 3.3 | 11.9 | 10.2 |
| | 8–24 | 0.2 | 1.2 | 1.1 | 1.2 |
| | 24–60 | 0.2 | 0.4 | 0.6 | 0.3 |
| K content, p.p.m. | 0– 8 | 69 | 105 | 81 | 132 |
| | 8–24 | 48 | 57 | 51 | 56 |
| | 24–60 | 49 | 51 | 46 | 52 |

* Treatment: O—no fertilizer; N—nitrogen; P—phosphate; K—potash.
** Expressed in terms of inches of water held per foot of soil.

TABLE 5.—EXPERIMENTAL STATION YIELD DATA

| | Plot 1 | Plot 2 |
|---|---|---|
| Treatment | N* | NP |
| Yield 1928-29** | 286 | 274 |
| 1930-31 | 459 | 437 |
| 1932-33 | 547 | 612 |
| 1934-35 | 636 | 598 |
| 1936-37 | 687 | 698 |
| 1938-39 | 770 | 817 |
| 1940-41 | 626 | 472 |
| Average yield per tree** | 653 | 639 |
| Average yield per acre*** | 987 | 967 |
| Biennial bearing index, McIntosh | 67.0 | 70.6 |
| Biennial bearing index, Delicious | 17.9 | 41.8 |
| Biennial bearing index, Rome | 49.3 | 35.1 |
| Biennial bearing index, Newtown | 82.7 | 67.8 |

* Treatments: N—nitrogen; P—phosphate.
** The yields are expressed in terms of pounds per tree. Those for 1928-31 represent the period prior to the initiation of differential treatment. The averages are determined from the 1932-41 yields only.
*** Expressed in terms of loose bushel boxes. To obtain these figures, the number of pounds is divided by 32.

were McIntosh, Delicious, Rome, and Newtown, planted 30 feet apart on the square in 1916. In 1932, 2 plots were laid out side by side with 10 trees of each variety in each plot, and treatments were applied from 1932 to 1941 as follows:

PLOT 1 (N): sulphate of ammonia, at the rate of 5 pounds per tree.

PLOT 2 (NP): ammonium phosphate 16-20, at the rate of 6.3 pounds per tree. This supplied nitrogen at the same rate as in Plot 1.

In both of these plots, hairy vetch was grown early in the experiment. Since then, the cover crop has consisted of a mixture of perennial and annual grasses. The yields were recorded before the initiation of differential treatment as well as after. They are summarized in Table 5, with 4 years of pre-treatment yields indicated. There was no apparent effect of phosphate either on the yields over a 10-year period or on the degree of biennial bearing. It will be noted that the McIntosh and Newtown varieties showed a greater tendency toward biennial bearing than did the Delicious and Rome varieties.

The fruit from each tree was graded for size during the 4 years 1936, 1937, 1938, and 1939. The size grades used were (a) under $2\frac{1}{4}$ inches, (b) $2\frac{1}{4}$

TABLE 6.—EXPERIMENTAL STATION SIZE AND COLOUR DATA

| | Plot 1 | Plot 2 |
|---|---|---|
| Treatment | N* | NP |
| 1936 | | |
| Yield per tree, lb. | 733 | 883 |
| % fruit over $2\frac{1}{2}$ in. | 91.5 | 90.3 |
| % fruit over 3 in. | 32.3 | 26.1 |
| % Fancy and Extra Fancy—McIntosh** | 93.5 | 89.5 |
| —Delicious | 88.6 | 77.5 |
| —Rome | 61.4 | 53.0 |
| 1937 | | |
| Yield per tree, lb. | 733 | 690 |
| % fruit over $2\frac{1}{2}$ in. | 86.8 | 79.6 |
| % fruit over 3 in. | 26.1 | 15.1 |
| % Fancy and Extra Fancy—McIntosh | 54.6 | 50.7 |
| —Delicious | 73.3 | 59.9 |
| —Rome | 26.1 | 17.8 |
| 1938 | | |
| Yield per tree, lb. | 911 | 996 |
| % fruit over $2\frac{1}{2}$ in. | 88.5 | 89.4 |
| % fruit over 3 in. | 27.0 | 26.4 |
| % Fancy and Extra Fancy—McIntosh | 69.0 | 54.4 |
| —Delicious | 70.0 | 45.3 |
| —Rome | 42.1 | 42.7 |
| 1939 | | |
| Yield per tree, lb. | 682 | 679 |
| % fruit over $2\frac{1}{2}$ in. | 76.5 | 88.8 |
| % fruit over 3 in. | 29.2 | 12.1 |
| % Fancy and Extra Fancy—McIntosh | 51.3 | 71.6 |
| —Delicious | 74.3 | 74.8 |
| —Rome | 37.8 | 54.2 |
| Four years | | |
| % fruit over $2\frac{1}{2}$ in. | 85.8 | 87.0 |
| % fruit over 3 in. | 28.6 | 19.9 |
| % Fancy and Extra Fancy | 61.9 | 57.5 |

* Treatments: N—nitrogen; P—phosphate.

** Red colour requirements for Fancy: McIntosh 25%, Delicious 25%, Rome 15%. Requirements for Extra Fancy were 50%, 50%, and 40%, respectively.

to 2½ inches, (c) 2½ to 3 inches, and (d) over 3 inches. The data obtained are presented in simplified form in Table 6. Taking the 4 years as a whole, there was no significant effect of phosphate on fruit size.

The fruit from each tree except the Newtowns was likewise graded for colour. For Extra Fancy grade, the amount of solid red colour required was 50% for McIntosh, 50% for Delicious, and 40% for Rome. For Fancy, the requirements were 25, 25, and 15%, respectively. There were no colour requirements for C Grade. The results are summarized by varieties in Table 6. During 1936, 1937 and 1938, the colour was quite definitely less in the phosphate plot. In 1938, however, the reverse was true. Taking the 4 years together, the differences were not great enough to justify attaching any special significance to them.

Soil samples were not obtained from these 2 plots until 1944. From 1941, when the experiment was discontinued, until 1944 the only fertilizer applied was sulphate of ammonia. The soil depth was greater than 60 inches in most of Plot 1, and less than 60 inches in most of Plot 2. The more pertinent of the soils data are presented in Table 7. It will be seen that the pH has been markedly reduced in the surface soil in both plots; also that the P content of the Plot 1 soil was comparatively low.

## BUTLER ORCHARD

The soil in this orchard is a shallow, sandy loam, of the Rutland Sandy Loam series (2). It varies in depth from 21 to 25 inches, and is underlain by a mixture of coarse sand and gravel. The permanent trees in the plot area were McIntosh, planted about 1908, 30 feet apart on the square. Jonathan fillers were planted in the centres of the squares. The cover crop consisted mostly of annual weeds. In 1928, a series of 5 plots was

Table 7.—Experimental Station soils data

| | Depth in in. | Plot 1 | Plot 2 |
|---|---|---|---|
| Treatment | — | N* | NP |
| Organic matter, % | 0– 8 | 2.2 | 1.8 |
| | 8–24 | 1.1 | 0.9 |
| | 24–60 | 0.4 | 0.4 |
| Lime content** | 0– 8 | None | None |
| | 8–24 | None | None |
| | 24–60 | Rich | Rich |
| pH | 0– 8 | 5.6 | 5.2 |
| | 8–24 | 7.7 | 7.6 |
| | 24–60 | 7.7 | 8.1 |
| Moisture capacity*** | 0– 8 | 4.0 | 3.6 |
| | 8–24 | 3.8 | 3.2 |
| | 24–60 | 2.0 | 1.8 |
| P content, p.p.m. | 0– 8 | 0.8 | 6.5 |
| | 8–24 | 0.2 | 1.6 |
| | 24–60 | 0.3 | 0.2 |

* Treatment: N—nitrogen; P—phosphate.
** Lime content determined by spot effervescence test.
*** Expressed in terms of inches of water held per foot of soil.

TABLE 8.—BUTLER YIELD AND VIGOUR DATA

| | Plot 1 | Plot 2 | Plot 3 | Plot 4 | Plot 5 | Plot 6 | Plot 7 | Plot 8 |
|---|---|---|---|---|---|---|---|---|
| Treatment | NP* | NPK1 | NPK2 | NPK3 | O | N | NP | NPK |
| Yield 1929-30** | 11.0 | 12.5 | 11.5 | 10.5 | 9.0 | — | — | — |
| 1931-32 | 11.0 | 11.5 | 13.5 | 14.0 | 11.5 | — | — | — |
| 1933-34 | 14.0 | 18.0 | 18.5 | 17.5 | 12.5 | — | — | — |
| 1935-36 | 13.5 | 20.5 | 19.5 | 21.5 | 13.5 | — | — | — |
| 1937-38 | 12.0 | 17.0 | 17.5 | 15.0 | 10.5 | 13.5 | 16.0 | 13.5 |
| 1939-40 | 18.0 | 24.5 | 24.5 | 23.0 | 9.0 | 24.0 | 28.0 | 28.0 |
| 1941-42 | 18.5 | 19.5 | 19.5 | 19.5 | 15.5 | 12.5 | 9.5 | 8.0 |
| 1943-44 | 18.0 | 22.0 | 18.5 | 15.5 | 9.0 | 15.5 | 14.0 | 15.0 |
| Average yield per tree, 1937-44 | 16.6 | 20.7 | 20.0 | 18.2 | 11.0 | 16.4 | 16.9 | 16.1 |
| Average yield per acre | 803 | 1001 | 968 | 881 | 532 | 793 | 818 | 779 |
| Per cent profitable yield | 80.4 | 84.3 | 87.1 | 87.9 | 87.1 | 82.7 | 80.5 | — |
| Biennial bearing index | 47.0 | 42.8 | 52.0 | 51.7 | 47.3 | 47.3 | 61.0 | — |
| Average increase in trunk circumference (cm.) | 2.7 | 2.2 | 2.2 | 2.1 | 1.4 | 2.9 | 3.0 | — |
| Average terminal length (cm.) | 27.2 | 25.4 | 25.8 | 25.2 | 24.7 | 28.1 | 26.7 | — |

* Treatments: O—no fertilizer; N—nitrogen; P—phosphate; K—potash. The potash supply was increased in the order of Plots 1, 2, 3, 4.

** The yields are expressed in terms of loose bushel boxes.

laid out side by side, and treatments have been applied from then until the present as follows:

PLOT 1 (NP). From 1928 to 1931, 4-10-0 was applied at the rate of 15 pounds per tree. From 1932 to 1936, 5 pounds of a 2 : 1 mixture of 16-20-0 and 11-48-0 were applied per tree. In 1937 and 1938, sufficient sulphate of ammonia was also applied to bring the actual nitrogen up to 1 pound per tree. This was omitted from 1939 to 1942, and continued again from 1943 to the present. From 1940 to the present, the ammonium phosphate mixture has been replaced with 5 pounds per tree of 16-20-0.

PLOT 2 (NPK1). From 1928 to 1931, 4-10-6 was applied, at the rate of 15 pounds per tree. From 1932 to the present, the same treatment has been given as in Plot 1, except for the addition of 1 pound of sulphate of potash per tree.

PLOT 3 (NPK2). From 1928 to 1931, 4-10-12 was applied at the rate of 15 pounds per tree. From 1932 to the present, the same treatment has been given as in Plot 1, except for the addition of 2 pounds of sulphate of potash per tree.

PLOT 4 (NPK3). From 1928 to 1931, 4-10-18 was applied at the rate of 15 pounds per tree. From 1932 to the present, the same treatment has been given as in Plot 1, except for the addition of 3 pounds of sulphate of potash per tree.

PLOT 5 (O). Check, no fertilizer.

Each of these five plots contained 2 rows of 5 McIntosh trees each, with buffer rows between plots. At the start of the test, Jonathan filler trees were scattered throughout the plots. In Plots 2 to 5, they were practically all removed in the first 4 or 5 years. They were not all removed from Plot 1, however, until 1939.

TABLE 9.—BUTLER SOILS DATA, 1940

| | Depth in in. | Plot 1 | Plot 2 | Plot 3 | Plot 4 | Plot 5 | Plot 6 | Plot 7 |
|---|---|---|---|---|---|---|---|---|
| Treatment | — | NP* | NPK1 | NPK2 | NPK3 | O | N | NP |
| Depth of solum, in. | — | 22 | 23 | 25 | 24 | 23 | 22 | 21 |
| Gravel, % | 0– 8 | 12.8 | 12.0 | 11.8 | 11.0 | 27.2 | 9.4 | 9.9 |
| | 8–24 | 59.4 | 53.8 | 46.4 | 47.4 | 58.0 | 46.4 | 45.1 |
| Organic matter, %** | 0– 8 | 2.7 | 2.3 | 1.9 | 1.9 | 1.9 | 1.4 | 2.0 |
| | 8–24 | 0.4 | 0.2 | 0.3 | 0.2 | 0.4 | 0.1 | 0.4 |
| pH | 0– 8 | 6.46 | 5.87 | 6.30 | 5.99 | 6.66 | 6.27 | 5.67 |
| | 8–24 | 6.36 | 6.34 | 6.34 | 6.36 | 6.46 | 6.51 | 6.15 |
| Moisture capacity** | 0– 8 | 2.9 | 2.7 | 2.8 | 2.8 | 2.4 | 2.7 | 2.8 |
| | 8–24 | 1.0 | 1.1 | 1.3 | 1.2 | 1.1 | 1.3 | 1.3 |
| P content, p.p.m.** | 0– 8 | 10.1 | 8.8 | 8.2 | 8.9 | 2.0 | 1.6 | 8.4 |
| | 8–24 | 0.5 | 0.5 | 1.1 | 0.8 | 0.2 | 0.2 | 0.5 |
| K content, p.p.m.** | 0– 8 | 79 | 105 | 110 | 180 | 74 | 80 | 80 |
| | 8–24 | 20 | 20 | 33 | 26 | 19 | 14 | 25 |

* Treatments: O—no fertilizer; N—nitrogen; P—phosphate; K—potash. The potash supply was increased in the order of Plots 1, 2, 3, 4.

** These determinations have been corrected for the percentage gravel, on the assumption that the moisture, P and K contents in soil particles over 3 mm. in size are zero. The moisture holding capacity is expressed as inches of water per foot of soil.

A second series of plots was started in 1932, with treatments as follows:

PLOT 6 (N). From 1932 to 1940, sulphate of ammonia was applied at the rate of 3 pounds per tree. This was increased in 1941 to 4 pounds per tree.

PLOT 7 (NP). From 1932 to 1940, sulphate of ammonia was applied at the rate of 3 pounds per tree, and triple superphosphate at the rate of 5 pounds per tree. In 1931, these were changed to 5 pounds of 16-20-0 per tree.

PLOT 8 (NPK). The same as Plot 7, except for the addition of 4 pounds of sulphate of potash per tree.

These plots are the same size and shape as Plots 1 to 5. Plot 6 lies adjacent to Plot 5. A few filler trees still persist in these 3 plots. In all 8 of the plots, the treatments are still being applied.

The yields are summarized by 2-year periods in Table 8. No yields were recorded in the second plot series until 1937. In order to make comparisons easier, the averages are calculated for the years 1937-44 throughout. The outstanding effect is the increased yield from applications of nitrogen. The yield is somewhat lower in Plot 1 than in Plots 2, 3 and 4, but this can be attributed to the later removal of the fillers in this plot. There is no evidence in Plots 6, 7 and 8 of any beneficial effect on yield from phosphate or potash. The percentage of fruit that was classed as profitable appears to have been affected very little by the fertilizers applied. The same can be said of the degree of biennial bearing. The most vigorous trees were in the second series of plots, and the least vigorous in the check plot.

The soils data are summarized in Table 9. No soil samples were obtained from Plot 8. It will be seen that the content of gravel and stones

is quite high, especially in the 8- to 24-inch layer. The pH was on the acid side in all plots. The content of available phosphorus was markedly increased in the top 8 inches by applications of phosphate, but not below that depth. The available potassium content was affected in similar manner by applications of potash.

## WILLITS ORCHARD

The soil in this orchard is a sandy loam, ranging around 27 to 30 inches in depth, and underlain by coarse sand and gravel. The trees are McIntosh, planted about 1922. During the period of the experiment, the cover crop consisted mostly of annual weeds. In 1932, a series of 4 plots was laid out side by side, with 2 rows of 5 trees each to the plot and no buffer rows between. The treatments (which are still being applied) have been as follows:

Plot 1 (O): check, no fertilizer.
Plot 2 (N): same as Butler Plot 6.
Plot 3 (NP): same as Butler Plot 7.
Plot 4 (NPK): same as Butler Plot 8.

Owing to a deficiency of boron in the soil, which caused drought spot and corky core conditions in the fruit, the yields were not recorded during the first 5 years of the test. This condition was corrected by applications of boric acid in the fall of 1936. The subsequent yields are summarized by 2-year periods in Table 10. It will be noted that the average yields were comparatively low in all 4 plots. The highest yields, the lowest quality of fruit, and the highest degree of tree vigour occurred in Plot 2, receiving sulphate of ammonia only. The variations in degree of biennial bearing were small. There is no evidence of any beneficial effect on either "total" yield or "profitable" yield from phosphate or potash. Nitrogen has increased the total yield, but its effect on profitable yield has been slight.

The soils data are summarized in Table 11. Due to an error, soil samples were not obtained from Plot 4. There was no gravel contained in the top 2 feet of soil. It will be seen that the fertilizers have lowered the pH somewhat, especially in the surface 8 inches, and that where phosphate was applied, the content of available phosphorus was increased markedly in the surface soil and slightly in the subsoil.

Table 10.—Willits yield and vigour data

| | Plot 1 | Plot 2 | Plot 3 | Plot 4 |
|---|---|---|---|---|
| Treatment | O* | N | NP | NPK |
| Yield 1937-38** | 19.0 | 13.0 | 18.5 | 19.0 |
| 1939-40 | 16.0 | 24.5 | 16.5 | 15.5 |
| 1941-42 | 7.0 | 7.0 | 6.0 | 5.5 |
| 1943-44 | 7.5 | 13.5 | 10.5 | 10.5 |
| Average yield per tree | 12.4 | 14.5 | 12.9 | 12.6 |
| Average yield per acre | 600 | 702 | 624 | 610 |
| Per cent profitable yield | 94.7 | 85.2 | 89.1 | 89.6 |
| Biennial bearing index | 45.2 | 40.0 | 45.7 | 41.0 |
| Average increase in trunk circumference (cm.) | 3.4 | 5.0 | 4.4 | 4.5 |
| Average terminal length (cm.) | 22.8 | 32.4 | 26.9 | 27.4 |

* Treatments: O—no fertilizer; N—nitrogen; P—phosphate; K—potassium.
** The yields are expressed in terms of loose bushel boxes.

## DISCUSSION

The 6 series of experiments reported herein provide evidence of the general need for nitrogen in Okanagan orchards. In some of the tests, this need was supplied in part by leguminous cover crops, so that the application of nitrogenous fertilizer had a relatively small effect. In other cases, the beneficial effects of nitrogenous fertilizers were quite marked. The greatest effect was in increasing the vigour and yield of the trees. As previously reported (6), in investigations covering a large part of the Okanagan Valley, an increase in the vigour of McIntosh trees has been accompanied by an increase in yield and a lowering of fruit quality. The highest yields of high quality fruit have occurred with an average terminal length of 10 to 12 inches. In this present experiment, the terminal length fell within this range in almost every plot in which it was measured.

There has been no definite evidence from these experiments of the need for applications of either phosphate or potash. There has as yet been no measurable beneficial effect of these fertilizers, either on yield or on fruit size or colour. It should be pointed out again that in the experiments reported herein the fertilizers were applied for at least 10 years. Analyses of the leaves and twigs indicate that in those plots receiving phosphate and potash, the roots have been taking in more phosphorus and potassium, respectively, than in those plots not receiving these elements. There can be no question, therefore, of the plants not having received any of the extra materials applied. The conclusion appears to be justified that if any of the soils tested are deficient in phosphorus or potassium, the deficiency has not yet been great enough to affect tree yields or vigour to any great extent.

In addition to the 6 series of tests reported herein, 21 other fertilizer experiments have been conducted in apple orchards in the Okanagan Valley, by the authors and by other technical workers. Most of these

TABLE 11.—WILLITS SOIL DATA

| | Depth in in. | Plot 1 | Plot 2 | Plot 3 |
|---|---|---|---|---|
| Treatment | — | O* | N | NP |
| Depth of solum, in. | — | 30 | 27 | 27 |
| Organic matter, % | 0– 8<br>8–30 | 1.7<br>0.7 | 1.4<br>0.7 | 1.8<br>0.9 |
| pH | 0– 8<br>8–30 | 6.93<br>7.10 | 6.21<br>6.68 | 5.82<br>6.78 |
| Moisture capacity | 0– 8<br>8–30 | 2.8<br>2.6 | 2.9<br>2.7 | 2.9<br>2.7 |
| P content, p.p.m. | 0– 8<br>8–30 | 1.4<br>0.3 | 0.8<br>0.3 | 16.4<br>2.6 |
| K content, p.p.m. | 0– 8<br>8–30 | 68<br>35 | 64<br>33 | 87<br>36 |

* Treatments: O—no fertilizer; N—nitrogen; P—phosphate.

tests have been of shorter duration than 10 years. In one of the shorter tests, the experimenter has reported (unpublished) better yields accompanying applications of superphosphate; but in no other case have beneficial effects from phosphate or potash been reported.

The soils of the Okanagan Valley are very variable, and it is recognized by the authors that all of the major variations within each soil series have not yet been tested by the field plot method. The question arises, therefore, as to whether the fertilizer results obtained can be applied generally throughout the area concerned. In order to check on this, further soil analyses are being made; and further field plot tests have been started in soils found to be lower in phosphorus and potassium than any of those in the tests outlined above.

It should be noted again that the fertilizers applied have caused a lowering of the pH in the surface soil. This can be attributed primarily to the use of sulphate of ammonia, though superphosphate and 16-20-0 also appear to have increased the acidity somewhat. Applications of phosphate and potash have markedly increased the contents of available phosphorus and potassium in the top 8 inches. Even after 10 years or more of application, however, they have had little if any effect on the soil below 8 inches in depth.

## SUMMARY

Fertilizer experiments were conducted in 5 apple orchards, located in 4 different soil types and in 5 different districts in the Okanagan Valley in British Columbia. They were run for periods of 10 years or longer in each case. The records taken included yield, fruit size and colour, tree vigour, and various soils data.

The yields were increased in 3 orchards by applications of fertilizers containing nitrogen. In one orchard the lack of increase from nitrogen could be attributed in part to the use of leguminous cover crops. In no case were the yields increased significantly by the application of phosphate or potash. The effects of fertilizers on tree vigour were variable, but somewhat similar on the whole to their effects on yield.

The effects of the fertilizers on fruit size and colour were not altogether consistent. On the whole, nitrogen tended to give larger size and less colour. Applications of phosphate and potash were accompanied by less colour in 2 of the orchards, but by no consistent difference in colour in the other 3 orchards.

The degree of biennial bearing was not affected in any consistent manner by any of the fertilizer treatments.

Applications of phosphate and potash increased markedly the contents of available phosphorus and potassium, respectively, in the top 8 inches of soil, but not below that depth. Sulphate of ammonia lowered the pH in the top 8 inches, but had little if any effect on the pH of the subsoil. Similar effects—though not as marked—were obtained with 16-20-0 on soil pH.

It is concluded that these experiments have provided good evidence of the need for nitrogen in Okanagan Valley orchards, but not of the need for phosphorus or potassium.

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# A STEMPHYLIUM LEAF SPOT ON POTATOES IN BRITISH COLUMBIA[1]

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During the course of an examination of leaf lesions collected as specimens for a study of Early Blight of potato, it was noted that some of the lesions were lighter brown in colour than those of typical Early Blight and that they lacked the characteristic concentric zonation associated with that disease. Subsequent examination of the sporulating lesions showed a species of *Stemphylium* to be associated with the atypical "Early Blight" although frequently *Alternaria solani* (E. & M.) J. & G., the causal organism of true Early Blight, was also present. Through the courtesy of Dr. J. W. Groves, Science Service, Ottawa, the *Stemphylium* species was identified as *S. consortiale* (Thüm.) Groves and Skolko. This organism has been isolated by Groves and Skolko (1) from the seeds of a number of agricultural crops in Canada but it has not been reported heretofore as a parasite on potato.

Three species of *Stemphylium* are recorded as being parasites on solanaceous plants. Weber (6) reports a foliage disease of tomatoes in Florida caused by *S. solani* Weber. Ramsey (4) describes a *Pleospora* rot of tomatoes; his fungus is called *P. Lycopersici* Marchal and Marchal, the name given by Marchal and Marchal (2) to the perfect stage of *Macrosporium sarcinaeforme* Cav., now a synonym of *S. sarcinaeforme* (Cav.) Wilts. Middleton (3) was able to prove the pathogenicity of *P. Lycopersici* on tomato but concludes that the imperfect stage of that fungus is incorrectly assumed by Marchal and Marchal (2) to be *M. sarcinaeforme*. Groves and Skolko (1) also believe this connection to be based on a misidentification and they suggest that *P. Lycopersici* will probably become a synonym of *P. herbarum* (Pers.) Rabenh., the sexual stage of *S. botryosum* Wallr.

Groves and Skolko (1) list *M. consortiale* Thüm. and *M. Zimmermannii* Roum. as synonyms of *S. consortiale* while *S. verruculosum* (Zimmerm.) Sacc., *S. asperulum* Sacc. and *S. congestum* Newton are considered to be probable synonyms.

Collections of material for use in this study were made during the summer months of 1943 to 1945, inclusive, and the sections of the province from which samples were taken would seem to indicate that the Stemphylium leaf spot has a distribution in British Columbia about the same as that of Early Blight.

## EXPERIMENTAL METHODS AND RESULTS

### Isolation of the Fungus

It was necessary to induce sporulation of the naturally occurring lesions of Stemphylium leaf spot and the following procedure proved

[1] An abridgement of a thesis submitted to the Department of Botany, University of British Columbia, in partial fulfilment of the requirements for the degree of Master of Science in Agriculture, granted October, 1946.

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satisfactory. The lesions were surface-sterilized, washed in sterile water, and then placed on waxed filter papers floating on sterile water in Petri dishes. After a period of time ranging from 3 to 5 days, the spore crop was examined through a binocular microscope (× 100) and with the aid of a moistened glass micro-needle single spores were isolated.

The spores were placed on a thin film of agar in a Petri dish and a microscope was used before and following germination to ascertain that single spores had been isolated. Small circles were made with India ink on the bottom of the Petri dish to facilitate finding the spore with the microscope. Several pure stock cultures were made in this way and all but one were abandoned when it was ascertained that they were all identical.

## Cultural Characteristics

The morphological characters of the mycelium, the conidiophores, and the conidia agree with those described by Groves and Skolko (1). The fungus grew readily on corn meal, bean pod, prune, oatmeal, and potato dextrose agar and during the three years that the organism was cultured there appeared no fruiting structures which in any way resembled the perfect or perithecial stage. The different types of agar produced no distinct differences in growth rate or habit. The fungus grew consistently well on 2% potato dextrose agar and so this medium was used in the study of physiological reactions.

The temperature relations of the fungus were determined by placing a triplicate series of Petri dish cultures in dark incubators at different constant temperatures. The cultures were permitted to grow for 10 days and after that time they were removed and the data taken. The low temperature at which growth is first prevented was not determined since some growth was perceptible at 7° C. The optimum temperature for growth was 28° to 30° C. and the maximum was slightly below 40° C.; no growth took place at 40° C. although growth was considerable at 35° C. With the exception of the colonies grown at 7° C., where aerial mycelium was abundant, the growth of the fungus at all temperatures was of the same general texture. Aerial mycelium was characteristically sparse and conidial production plentiful. Slight instability was noted in the cultures at 22° and 28° C. while growth at 35° C. was typical of the normal development.

Potato dextrose agar adjusted to different pH values was used to test the growth of the fungus at different H-ion concentrations. No growth of the fungus took place when the agar substrate was adjusted to pH 3.8. At pH 4.2 the growth was quite characteristic but definitely restricted. Aerial mycelium was sparse and conidial production was copious within the pH range 4.2 to 6.1. The greatest amount of growth took place at pH 6.95 but the inhibiting effect of the alkali was not pronounced below pH 10.5. The growth between pH 8.5 and 9.75 was typical of the normal development of the fungus.

## Pathogenicity

The fungus, *S. consortiale* grew and produced conidia abundantly in culture and the conidia thus produced were used as inoculum for determining the pathogenicity and the suscept range of the fungus. A heavy

spore suspension was obtained by loosening the conidia in water by means of a scalpel or flattened glass stirring rod. Care was taken not to dislodge large masses of mycelium that would be likely to clog a deVilbiss atomizer.

Attempts to prove the pathogenicity of the fungus with a water suspension of spores failed, probably because the atmosphere in the incubation chamber was not adequately humid. The atomized leaves of the host plants were found to be quite dry when they were removed from the incubation chamber 24 to 36 hours after inoculation. To correct this lack of humidity a spore suspension was made in a solution consisting of 1 part glycerine to 4 parts water. Aseptic methods were followed during the preparation of the spore suspension.

With the exception of the potatoes which were grown from tubers in pots, the plants which were inoculated were grown in the greenhouse in seedbeds and later placed in pots. The plants were all inoculated at a stage of growth prior to or during flowering. The inoculum was atomized on to the foliage and stems so that the plant parts were entirely wetted by it. The leaves were not rubbed or wounded either prior to or after being inoculated. After they were inoculated the plants were placed in an incubation chamber for a period of 24 to 36 hours, and they were then removed and placed on a greenhouse bench at a temperature of 70° to 80° F. The plants were examined daily and usually the first symptoms appeared within 3 or 4 days after inoculation. Check plants were atomized with the glycerine and water solution and placed in the incubation chamber at the same time as the inoculated plants. No lesions appeared on the foliage of the checks.

The inoculation experiments were conducted during the months of April and May, 1946. The plants used in these experiments were representatives of the Solanaceae. Attempts to re-isolate the fungus were successful only in the case of the tomato (*Lycopersicon esculentum* Mill var. *John Baer*) and the potato (*Solanum tuberosum* L. var. *Katahdin*). In both of these instances the fungus could be identified readily by the conidia produced in culture and inoculations with each isolate produced the characteristic lesions on both tomato and potato foliage.

Numerous lesions appeared on the tomato within 72 hours after inoculation. They occurred first on the leaf blades but also developed on stems, petioles and sepals. The young lesions were dark brown with an irregular hydrotic margin and varied in size up to 20 mm. in diameter. Many adjacent lesions later coalesced and their colour became very light brown. These symptoms are shown in Figure 1. With the exception of the few leaves of new growth at the top of the plant, complete defoliation occurred within 8 to 12 days.

The lesions on the potato, unlike those on the tomato, were confined to the leaf blades. The first symptoms appeared in 3 days after inoculation. More advanced symptoms were visible in 5 to 8 days and consisted of a general yellowing of the lower leaves and a coalescence of many of the lesions which varied from 1 to 10 mm. in diameter. Figure 2 shows these symptoms on leaves that were inoculated 10 days before being photographed. The necrotic area thus formed involved in some cases almost the

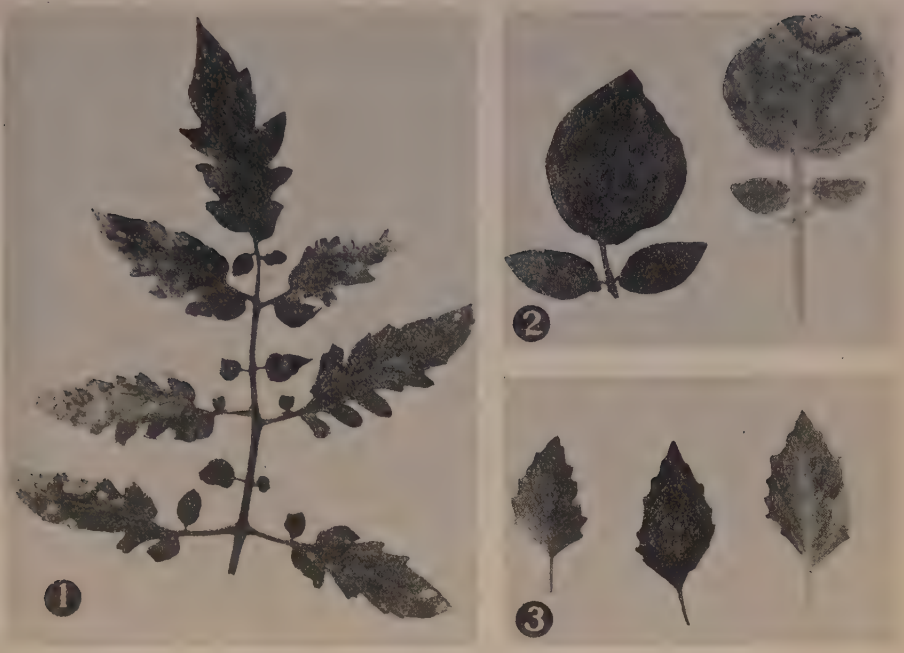


FIGURE 1. Leaf of tomato plant inoculated with *S. consortiale.*

FIGURE 2. Leaves of potato inoculated with *S. consortiale* and showing general yellowing of lower leaf on right.

FIGURE 3. Leaves of Black Nightshade inoculated with *S. consortiale.*

entire blade of a lower leaflet. Defoliation of the plants began with the lower leaves and within 2 weeks after inoculation almost complete defoliation had occurred.

## SUSCEPT RANGE

In addition to the potato and tomato a number of other solanaceous plants were included in the inoculation studies in an attempt to determine the suscept range of the fungus within the Solanaceae. Although the pathogenicity of the organism has been proven by the necessary re-isolations only on the potato and the tomato, leaf lesions appeared on inoculated leaves of Jimson Weed (*Datura Stramonium* L.), Tobacco (*Nicotiana Tabacum* L.), Ornamental tobacco (*N. alata* L.), and Black Nightshade (*Solanum Nigrum* L.). The lesions and general yellowing that occurred on leaves of *S. Nigrum* are shown in Figure 3. Since no lesions appeared on check plants of these species they are believed to be susceptible to infection by *S. consortiale.* Under the existing experimental conditions, the following plants showed immunity to *S. consortiale* infection: Red Pepper (*Capsicum annuum* L.), Eggplant (*Solanum Melongena* L.), Petunia (*Petunia hybride* Vilm.), *Salpiglossis* sp. and *Schizanthus* sp.

## PATHOLOGICAL HISTOLOGY

The spores of *Stemphylium consortiale* germinated readily within 5 hours in water and in the glycerine and water solution referred to previously. Spore suspensions in each of these media in a hanging drop culture in

Van Tiegham cells were observed microscopically over a period of several days. No difference in the time required for germination or in later development was noted.

Histological studies on the relation between pathogene and suscept were made using artificially inoculated leaves as material. A modification of the lacto-phenol method of Rawlins (5) was used in an attempt to make apparent the mode of entry of the fungus. Fresh leaf tissue was boiled in absolute alcohol for 5 minutes to remove the chlorophyll and other pigments and to fix the tissue. The tissue was then transferred to lacto-phenol for clearing. It was held in hot (not boiling) lacto-phenol for a few minutes and then rapidly cooled. A few drops of cotton-blue stain were added to the lacto-phenol, the concentration being determined by experimentation. The cleared and stained material was mounted in lacto-phenol.

Leaf tissues in which lesions were located were fixed in Karpechenko's solution (5), imbedded in paraffin, sectioned, stained with safranin and light green and mounted in Canada balsam by the usual histological procedures.

A study of the above preparations indicates that after artificial inoculations at least, the fungus spores germinate in the presence of moisture on the leaf surface and the hyphae penetrate the epidermis (probably through stomata or directly through cell walls following their being weakened by some substance supplied by the fungus). The mycelium then grows intercellularly and after 3 days the infection can be distinguished macroscopically because of the browning of the killed cells.

## DISCUSSION

Wherever lesions caused by infection of *Stemphylium consortiale* have been found in nature they have been associated with *Alternaria solani* infections and it is possible that, in British Columbia at least, the Stemphylium leaf spot has been included in the general conception of Early Blight. Both of these maladies are favoured by humid conditions when they occur toward the end of the growing season. More data regarding the natural occurrence of *S. consortiale* infection must be obtained before an estimate of its economic importance can be made. The organism probably overwinters on decaying organic matter in the vicinity of potato fields and no doubt the spores are spread over long distances by wind. It is conceivable that if proper conditions of extreme humidity and high temperatures prevailed an epidemic could occur.

## SUMMARY

1. The fungus *Stemphylium consortiale* (Thüm.) Groves and Skolko has been isolated from a hitherto undescribed leaf lesion on potatoes which is now designated as Stemphylium leaf spot.

2. The foliage symptoms of Stemphylium leaf spot differ from those of Early Blight in so far as the former are a generally lighter brown colour and the concentric zonations typical of Early Blight lesions are lacking or indistinct.

3. The fungus proved pathogenic on foliage of potato, *Solanum tuberosum* var. *Katahdin* and tomato *Lycopersicon esculentum* var. *John Baer*. Other apparent suscepts in the Solanaceae are *Datura Stramonium*, *Nicotiana alata*, *N. Tabacum*, and *Solanum Nigrum*.

4. The optimum temperature for growth of the fungus in culture was 28° C. and the optimum pH of the substrate was pH 6.95.

## ACKNOWLEDGMENTS

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# THE DETERMINATION OF COBALT IN PLANT MATERIALS[1]

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A deficiency of cobalt in the diet of sheep is responsible for the coast disease (8) and bush sickness (4) of Australia and New Zealand and the pine disease (2) of Scotland. The determination of cobalt has been investigated extensively in those countries. There is some evidence that cobalt deficient areas exist in Canada (1). Before a survey can be undertaken to establish the presence and extent of such areas, a reliable method for the determination of cobalt in Canadian pastures and feeds is necessary.

The work presented in this paper was carried out to investigate and compare methods of cobalt determination as applied to Canadian feeding stuffs. The experimental work involved a study of methods of extracting cobalt from plant materials, the use of a buffer for adjusting the pH of the extract prior to the development of colour and the factors affecting the cobalt-nitroso-R complex.

## METHODS OF EXTRACTION INVESTIGATED

The first step in the determination of cobalt is the extraction of cobalt from the sample. Both ashing and digestion methods have been used for this purpose. After a preliminary survey it was decided to compare three ashing and three digestion methods. These were:

*(a) Nitric Ash.* The sample was treated three times with nitric acid and ashed after each treatment following the method of Kidson and Askew (5). Ashing was carried out at 600° C. for 30 minutes. After the addition of 30 ml. of 1 : 1 HCl to the residue the procedure was modified by taking the extract to dryness on a sandbath. The residue was extracted with 0.5 ml. N/2 HCl and hot water. It was then filtered, washed and the volume of the filtrate reduced by boiling. Finally it was made to volume in a 25 ml. volumetric flask.

*(b) Sulphuric Ash.* The sample was treated first with 10 ml. concentrated $H_2SO_4$ (10), then with 10 ml. 1 : 1 $HNO_3$, being dried and ashed after each treatment with acid. 30 ml. 1 : 1 HCl were added to the residue and taken to dryness on the sandbath; then the method was continued as in *(a)*.

*(c) Dry Ash.* The sample was ashed in a silica basin for 3 hours at 500° C. 30 ml. 1 : 1 HCl were added and the method continued as in (*a*).

*(d) Sulphuric Digestion.* The sample was heated in a 500 ml. Kjeldahl flask with 100 ml. $H_2SO_4$ and 100 ml. $H_2O$ according to the method of Kidson, Askew and Dixon (6) and finally taken to dryness. The residue was treated with 30 ml. 1 : 1 HCl and brought to a boil. It was filtered, washed and the filtrate taken to dryness on a sandbath. It was then extracted with 0.5 ml. N/2 HCl and hot water as in (*a*).

*(e) Perchloric Digestion.* To the sample in a 600 ml. beaker 75 ml. $HNO_3$ were added and it was allowed to stand over night in the fume cupboard covered by a watch glass. While still covered the volume was

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reduced to approximately 15 ml. by boiling, 20 ml. $HClO_4$ were added and the boiling continued, with the evolution of dense white fumes, until the volume was reduced to approximately 10 ml. Gerritz (3) made use of perchloric acid in the digestion of samples for the determination of calcium and phosphorus. The residue from this treatment was transferred with water and filtered into a 250 ml. beaker, then taken to dryness on a sand-bath. 30 ml. 1 : 1 HCl were added and the method continued as in *(d)*.

*(f) Mixed Digestion.* The sample with 160 ml. $HNO_3$, 10 ml. $HClO_4$ and 6 ml. $H_2SO_4$ was boiled in a 500 ml. Kjeldahl flask until the volume was reduced to approximately 5 ml. (9). This was transferred with water to a 250 ml. beaker and taken to dryness on the sandbath, then the method continued as in *(e)*.

It was necessary to take the acid extracts to dryness in every case or the amount of potassium hydroxide used later to adjust the pH was excessive.

## THE ANALYSIS OF TEST SAMPLES

By each of these six methods quadruplicate extractions were made on the following samples:

10 gm. hay
10 gm. hay + 0.1 mg. cobalt
10 gm. hay + 0.2 mg. cobalt.

The hay was finely ground. The cobalt was added as cobalt chloride solution containing 0.1 mg. cobalt in 1 ml. of solution. Two blank determinations were carried out by each method.

The amount of cobalt in the extracts of the samples of hay with added cobalt was determined in a 2 ml. aliquot of the extracts. A 5 ml. aliquot of the extracts from the hay alone was used. To determine the cobalt the depth of colour of the complex formed between cobalt and nitroso-R-salt was measured in a Klett Summerson colorimeter using the green filter No. 54 with water set at zero. After the addition of 2 ml. of 0.1% nitroso-R-salt and 1 gm. of anhydrous sodium acetate to the aliquot, the procedure of Macpherson and Stewart (7) was followed except that the solutions were finally filtered into 15 ml. volumetrics and made to volume. Two blanks were run at the same time and the reading of these subtracted from those of the extracts to give the corrected colorimeter readings. A regression equation was established using 21 aliquots of a standard cobalt chloride solution containing from 0.5 to 25 mcgm. cobalt. The equation was $Y = 0.1261536\ X - 0.086636$ where Y is cobalt in mcgm. and X is the corrected colorimeter reading. The correlation was 0.9994 and the standard error of prediction $\pm 0.22$. The cobalt in the extracts was calculated from this equation.

## THE USE OF A BUFFER

It seemed that a buffer would be useful to adjust the pH of the extract in place of an indicator and two reagents used by Macpherson and Stewart (7). Various buffers at pH 5.0 were tested and one containing 20.2 ml. of glacial acetic acid and 69.3888 gm. of anhydrous sodium acetate per litre was found to be satisfactory.

The cobalt in the extracts was determined using this buffer by adding 2 ml. of 0.1% nitroso-R-salt and 5 ml. of buffer to the aliquot. The solutions were boiled for 2 minutes, then 5 ml. of $HNO_3$ were added and the method continued as before.

Using the buffer a second regression equation was established. This was $Y = 0.133155\ X - 0.084459$. The correlation was 0.9993 and the standard error of prediction was $\pm 0.26$.

## FACTORS AFFECTING THE COBALT COMPLEX

*(a) Light.* The colour developed in cobalt standards fades on standing (10). A group of standards was left for 24 hours after the colour had been developed. When these were read in the colorimeter the readings were lower than those obtained when the standards were read immediately after the colour was formed, but the blanks were lower also and the corrected readings were the same. Therefore the use of a blank allows for any effect of light.

*(b) Filtration.* It is necessary to filter all solutions before they are made to volume to be read (7). When a graph was plotted from readings of unfiltered standards, the line did not pass through the origin.

*(c) Presence of Iron.* Using solutions of standard cobalt chloride with varying amounts of added ferric chloride, the effect of the presence of iron on the determinations of cobalt was tested as well as the effect of

TABLE 1.—COBALT RECOVERED IN SAMPLES OF HAY WITH ADDED COBALT, USING SIX METHODS OF EXTRACTING THE COBALT AND TWO METHODS OF DETERMINING IT. RESULTS EXPRESSED IN MICROGRAMS

| Sample Analysed | Cobalt recovered in mcgms. by the following methods: | | | | | |
|---|---|---|---|---|---|---|
| | $HNO_3$ Ash | $H_2SO_4$ Ash | Dry Ash | $H_2SO_4$ Dig. | $HClO_4$ Dig. | Mixed Dig. |
| | *Phenolphthalein used to adjust the pH* | | | | | |
| 10 gm. hay + 100 mcgm. Co. | 92.2 | 84.6 | 84.2 | 90.4 | 86.6 | 94.4 |
| | 86.0 | 83.5 | 81.1 | 96.1 | 83.5 | 92.5 |
| | 85.0 | 84.8 | 80.5 | 92.0 | 93.5 | 94.4 |
| | 93.7 | 86.5 | 80.5 | 90.4 | 93.0 | 94.4 |
| 10 gm. hay + 200 mcgm. Co. | 172.4 | 164.4 | 167.6 | 183.4 | 187.4 | 179.9 |
| | 179.5 | 181.8 | 185.2 | 189.2 | 194.5 | 187.1 |
| | 176.2 | 183.4 | 180.2 | 187.6 | 181.8 | 187.1 |
| | 188.1 | 162.9 | 164.3 | 174.8 | 181.0 | 194.7 |
| | *Buffer used to adjust the pH* | | | | | |
| 10 gm. hay + 100 mcgm. Co. | 90.7 | 84.4 | 95.7 | 85.5 | 92.2 | 93.6 |
| | 87.0 | 85.5 | 95.0 | 70.0 | 93.8 | 95.7 |
| | 92.5 | 87.2 | 99.7 | 90.5 | 98.8 | 72.4 |
| | 92.5 | 81.5 | 93.7 | 89.7 | 100.5 | 97.7 |
| 10 gm. hay + 200 mcgm. Co. | 176.2 | 172.0 | 193.6 | 170.4 | 195.4 | 181.6 |
| | 177.8 | 169.6 | 204.8 | 191.2 | 198.7 | 172.3 |
| | 173.7 | 171.2 | 204.2 | 182.6 | 197.8 | 192.8 |
| | 177.8 | 154.6 | 208.2 | 190.4 | 201.2 | 198.9 |

TABLE 2.—THE ANALYSIS OF VARIANCE FOR FIGURES GIVEN IN TABLE 1 WHEN CALCULATED AS PER CENT RECOVERY

| Variance due to | Degrees of Freedom | Sums of Squares | Variance | F |
|---|---|---|---|---|
| Method | 5 | 866.40 | 173.28 | 8.29 |
| Quantity | 1 | 117.26 | 117.26 | 5.61 |
| pH Adjustment | 1 | 110.72 | 110.72 | 5.30 |
| Method × Quantity | 5 | 118.56 | 23.71 | 1.13 |
| Method × pH Adjustment | 5 | 984.55 | 196.91 | 9.42 |
| Quantity × pH Adjustment | 1 | 3.80 | 3.80 | * |
| Method × Quantity × pH Adjustment | 5 | 95.67 | 19.13 | * |
| Error | 72 | 1,505.27 | 20.91 | |
| Total | 95 | 3,802.23 | | |

* Less than variance for error.

Necessary F at p = 0.05 is 2.35 and 3.98,
at p = 0.01 is 3.29 and 7.01.

TABLE 3.—MEANS FOR THE METHODS OF EXTRACTING COBALT

| | $HNO_3$ Ash | $H_2SO_4$ Ash | Dry Ash | $H_2SO_4$ Dig. | $HClO_4$ Dig. | Mixed Dig. | Mean |
|---|---|---|---|---|---|---|---|
| Buffer | 89.4 | 84.0 | 98.7 | 87.9 | 97.7 | 91.5 | 91.5 |
| Phenolphthalein | 89.4 | 85.7 | 84.4 | 92.1 | 91.1 | 93.8 | 89.4 |
| Total | 89.4 | 84.9 | 91.7 | 90.0 | 94.4 | 92.6 | 90.5 |

nec. diff. for 16 values is 3.23 at p = 0.05 and 4.29 at p = 0.01,
8 values is 4.54 at p = 0.05 and 6.03 at p = 0.01.

removing iron by shaking with ether (5) and precipitation with zinc oxide (7). These tests confirmed the results of Macpherson and Stewart that iron does not interfere with the determination of cobalt and that, if its removal is desired, the use of ether is unsatisfactory for the purpose while the use of zinc oxide gives good results.

*(d) Presence of Copper.* The effect of the presence of copper and of its removal by hydrogen sulphide (7) and aluminum foil (7) was determined using standard cobalt solutions to which varying amounts of copper sulphate were added. The presence of copper in any appreciable quantity interfered with the determination of cobalt. The use of hydrogen sulphide for the removal of copper from acidified standards was satisfactory, but aluminum foil was not.

## RESULTS OF ANALYSES

The amounts of cobalt found in the extracts of the samples analysed are given in Table I. Results using both phenolphthalein and the buffer are listed. No cobalt was found in a 5 ml. aliquot of the extracts from the hay alone.

With the buffer there is one very low result in the sulphuric digestion extracts (70.0) and one in the mixed digestion extracts (72.4). These are probably due to the incomplete removal of sulphuric acid from the residue. It is difficult to remove the last traces of this acid. Because of this and

the fact that the average fume cupboard is not equipped to deal adequately with sulphuric fumes, it was decided that these methods were not practical for general use.

The results in Table I were expressed as per cent recovery and analysed statistically. The analysis of variance for these figures is given in Table II. Table III lists the mean per cent recovery for each method and the necessary differences for significance.

Considering the quantity of cobalt added, the mean recovery for 0.1 mg. was 89.4% and for 0.02 mg. was 91.6%. This is a difference of 2.2 absolute per cent which is significant at the 5% point but not at the 1% point. This significance is probably due to the fact that any error when applied to 0.1 mg. is double the same error applied to 0.2 mg. There was no interaction between quantity and method or pH adjustment.

Using phenolphthalein the recovery of cobalt varied from 84.4% to 93.8% with a mean of 89.4%. When the buffer was used the recovery ranged from 84.0 to 98.7% with a mean of 91.5%. The buffer results average 2.1 absolute per cent higher. This difference is significant at the 5% point but not at the 1% point.

The variances due to method and the interaction of method and pH adjustment were significant. Considering method only and omitting the sulphuric and mixed digestion results, the perchloric digestion method gave the best results. These results were not significantly higher than those of the dry ash method, but were significantly higher than those of the nitric ash methods. The sulphuric ash method gave the poorest results.

The significance of the interaction between method of extraction and pH adjustment was due to the fact that, when the buffer was used, the dry ash method produced results which were significantly higher than all but the perchloric digestion results, but, when phenolphthalein was used, the dry ash results were the lowest.

For the best recovery of added cobalt the dry ash or perchloric digestion method should be used coupled with the buffer.

## THE ANALYSIS OF PLANT MATERIALS

Thus far only the recovery of added cobalt has been considered. This is the usual basis for the selection of a method of analysis. It was decided to test the methods for the extraction of naturally occurring cobalt from a variety of plant materials. Six samples were selected for analysis. These

TABLE 4.—THE COBALT CONTENT OF VARIOUS PLANT MATERIALS AS DETERMINED BY DIFFERENT METHODS OF EXTRACTION

| Sample Analysed | Cobalt, in p.p.m., determined by the following methods: | | | |
|---|---|---|---|---|
| | $HNO_3$ Ash | $H_2SO_4$ Ash | Dry Ash | $HClO_4$ Dig. |
| Carrots | 0.05 | 0.11 | 0.03 | 0.09 |
| Hay | 0.08 | 0.06 | 0 | 0.08 |
| Oats | 0.07 | 0.02 | 0 | 0.12 |
| Corn Silage | 0.12 | 0.08 | 0.03 | 0.11 |
| Red Clover | 0.05 | 0.09 | 0.03 | 0.13 |
| Soybeans | 0.07 | 0.03 | 0.03 | 0.07 |
| Mean | 0.07 | 0.07 | 0.02 | 0.10 |

were dried carrots, hay, oats, dried corn silage, dried red clover and soybeans. Duplicate determinations were made on ten gram samples by the perchloric digestion and the three ash methods. The extract from the entire sample was used to determine the cobalt present. The colour was developed in the presence of the buffer. The results of these analyses are given in Table IV.

The relative efficiency of the methods for the recovery of cobalt added to plant materials differs from that for the extraction of cobalt from plant tissues. For the recovery of added cobalt there was no significant difference between the perchloric digestion and dry ash methods. For the extraction of naturally occurring cobalt the perchloric digestion method gave the best results and the dry ash the poorest. It would appear that the recovery of added cobalt is not a reliable criterion for the selection of an extraction method. On the basis of the extraction of naturally occurring cobalt, it is recommended that the perchloric digestion method be used for the determination of cobalt.

## SUMMARY AND CONCLUSIONS

Six methods of extraction were used to determine cobalt in samples of hay with cobalt added and four of these methods were used to determine the cobalt occurring naturally in feedstuffs.

The amount of cobalt was estimated by the depth of colour of the cobalt-nitroso-R-complex developed in the extract as read in a Klett-Summerson colorimeter.

The use of blank determinations compensated for any impurities in the reagents used and for the effect of light on the colour of the complex.

Copper interfered with the determination of cobalt and was removed by precipitation with hydrogen sulphide.

Iron did not interfere with the determination of cobalt.

The use of a buffer simplified the procedure and gave better results.

Of those tested, the perchloric digestion method was the most satisfactory for the extraction of cobalt.

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## BOOK REVIEWS

FEEDING POULTRY. By G. F. HEUSER. Poultry Science Series. Published by John Wiley and Sons. 543 pp. Illustrated. $4.50.

Of all phases of poultry production, that of feeding is perhaps the most important. As a result a great amount of research has been carried out in this field and advancement has been rapid. On this account it is very difficult for the layman to keep abreast of the increasing knowledge available and a reference book "at the layman's level" supplies a very obvious need. At the same time, it is very desirable that such a reference be suitable also for the use of the student and extension man. The author has attempted to present "both the scientific and practical facts relating to poultry feeding" and in the opinion of this reviewer has done so very creditably. Since much of the information drawn upon is contradictory, it is necessary to attempt to evaluate it, a very difficult assignment hardly possible except by one who has had a long and broad experience in the field of poultry nutrition. These requirements are undoubtedly well met by the author.

As to the organization of the book, the various sections have been given weight appropriate to their importance. There might be mentioned a section, not too technical on the feed nutrients and their functions; on vitamins and vitamin deficiencies (well illustrated); on grains and their by-products. and animal and vegetable protein feeds. Under protein, there is an excellent table on amino acid content of feeds. The tables of average composition of feedstuffs, however, are not as extensive as they might well have been.

The section on pastures and greenfeed should be mentioned as an important contribution, particularly in times of shortages of protein materials as at present.

The book is well indexed and has an adequate bibliography. All things considered, the book constitutes a valuable addition to the library of the specialist or poultryman.

H. S. GUTTERIDGE.

PHOSPHATES AND SUPERPHOSPHATES. By A. N. Gray. Second Edition, London, October, 1943. Interscience Publishers, Inc., New York 3, New York. Printed in England by E. T. Heron & Co., Ltd.

One of the main objects of the author in preparing this book was its use as a reference text. It is well suited for this purpose, containing 155 statistical tables on production, trade and consumption figures for phosphate rock, superphosphates, basic slags and phosphoric acid. In addition, numerous other tables are to be found distributed through the text. The subject matter is well written and covers the history of the industry, methods of production, and factors governing world trade and consumption. It contains, in addition, many other interesting facts.

The importance of this book from the point of view of agriculture is found in the author's statement that over 95 per cent of the world's output of phosphate rock is utilized, directly or indirectly, for fertilizer purposes, and nearly 80 per cent of the phosphate rock mined and sold is converted

to superphosphate. While the rate at which this material is used has shown a considerable increase in the past 20 or 25 years, the known reserves of phosphate rock, approximately 17 billion tons, are sufficient for 1,300 years at the 1938 rate of consumption.

The first edition of this book was published in 1930 and the present (second) edition in 1943. For anyone interested in statistics on phosphates and superphosphates, this book should be most useful.

H. J. Atkinson.

Crop Production and Environment. By R. O. Whyte. Faber and Faber, London, 1946. 372 pp. 25 shillings.

The president of a scientific society once announced that his presidential address was entitled "Missing the Boat". Some members, knowing that the president was a bit of a wag, expected the address to be mostly humorous and were somewhat disappointed to find that most of it was strictly scientific. Other members, taking the title at face value, stayed away and missed an excellent and informative address.

To the reviewer, the title of Whyte's book "misses the boat" and, as a result, many readers will be disappointed in its contents; while others, who will welcome such a book as this, will little suspect the true nature of the material. The author frequently refers to "Developmental Physiology of Plants", and this would have been a much more suitable title. Crop production in relation to environment must be concerned with more than the relation between the physiological development of the plant and the environmental factors of temperature and light. Moisture has a profound influence on crop production, particularly in areas like western Canada, but in this book is referred to only casually in its relation to temperature and light effects. The basic philosophy behind this book appears to be contained in a statement on p. 210: "The most important factors as regards true development of crop plants are, of course, the seasonal and daily trends in temperature and the length of the daily periods of light and darkness." One may add that in many parts of the world where crop production is carried on extensively the main limiting factor (and therefore one of the most important factors) determining yields is moisture. The title, "Crop Production and Environment" is too general for this book.

The above is not to be taken as a criticism of the material in the book—far from it. The author has succeeded in presenting and discussing an enormous amount of material in an extremely useful and informative manner. He has, to use his own words in slightly altered sequence, "attempted to bring out the views and experiences of scientists past and present, weather-wise farmers, gardeners with green fingers, and cultivators of all manner of crops in every cultivable latitude." The result is a book that will be valuable chiefly as a reference for the research worker.

Dominating the presentation throughout the book is the discussion centering around vernalization, photoperiodism, and hormones. The wide range of interaction between temperature and light reactions on the growth and reproduction of plants is stressed. The author begins with the early work of Klebs, Gassner, Garner and Allard, and others, and then deals

extensively with the work of the Russians, particularly Lysenko. The basic factors of growth and development are thoroughly reviewed, and lay the foundation for the discussion of the effects of environment in determining the distribution of plants. There is a chapter on the analysis of environmental requirements in relation to plant breeding, while several chapters are devoted to a consideration of the developmental physiology of economic plants. The plants discussed include among others the cereals, sugar beets, legumes, potatoes, vegetables, flowers, and trees, all of which are of interest to Canadians.

The author has included references to work done in many countries and under very wide ranges of conditions. There are numerous excellent illustrations, the plates being particularly good. Tables, graphs, and diagrams are extensively used. As a source of information on developmental physiology of plants the book stands alone, and can be unreservedly recommended to all workers in this and related fields of study.

A. G. McCalla

## ERRATUM

In Scientific Agriculture Vol. 26, No. 12, December, 1946, page 656, "Seed Potato Districts and Virus Diseases in Quebec", change Table 1 to read as follows in the last three columns of figures:

| F | F–A | C |
|---|---|---|
| 4.6 | 37.6 | 57.7 |
| 5.7 | 46.7 | 47.5 |
| 5.4 | 64.1 | 30.4 |
| 5.4 | 70.8 | 23.7 |
| — | .2 | — |

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